IDENTIFYING AND ADDRESSING DRIVERS AND BARRIERS TO RENEWABLE ENERGY DEVELOPMENT IN THE RURAL ELECTRIFICATION OF MONGOLIA

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Declaration

I declare that this dissertation is my own account of my research and contains, as its main content, work which has not previously been submitted for a degree at any tertiary education institution.

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Abstract

Historically, in rural areas of many countries, diesel generators have been used as a centralized power supply option at the centre of small villages. The viability of this option depends on many factors which are different in each country's specific situation. However, there are some problems that can be common despite their different situations. For example, a difficulty in transporting diesel fuel to remote rural areas is common and can be often impossible due to bad weather conditions. High transportation costs for diesel fuel and the high price of diesel fuel itself are also similar for many countries. Insufficient maintenance and periodic major overhaul of diesel generators is commonly due to lack of qualified people or supervisory organization and the low level of power tariffs. People living in remote rural areas have low income and so their ability to pay is low. On the contrary, the price of diesel fuel increases consistently and many countries have to import diesel fuel from other countries. Thus, for some countries nowadays, a centralized power supply solution using a diesel generator, is not a promising solution for rural areas. Alternative solutions have been sought by governments of many countries, focusing on utilizing renewable energy as an option for power supply in remote rural areas.

Renewable energy has been utilized widely in rural areas of many countries however, only in small-scale systems for individual households or single organizations but not often as a large centralized power supply at the centre of villages where the magnitude and change of load are significant. Although, renewable energy systems have less operating costs than diesel generators, their initial capital cost is high and their technology requires a different strategy for ensuring their sustainable functioning in rural areas. There are many technical and non-technical issues that need to be considered.

Sustainability of renewable energy systems in rural areas depends on success in each stage of implementation of a project, and various drivers and barriers exist in renewable energy utilization for rural electrification. The Government of Mongolia had financed implementation of 12 projects for installation and operation of the centralized type of renewable energy systems at the centre of remote rural soums (villages) between 2007 and 2008.

In this dissertation, drivers and barriers to renewable energy development in the rural electrification of Mongolia were identified and addressed, based on real facts in installation and operation of 12 large-sized renewable energy systems in rural areas of Mongolia. Information about similar types of projects implemented elsewhere is not abundant that cannot

be referenced as real-life examples. There is no simple guide to considering all related issues for implementation of large-sized, centralized-type of renewable energy systems intended to be installed in the centre of rural villages. Most of the issues identified in this dissertation can be similar for many countries, despite the specific circumstances of each country.

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List of Acronyms

ADB	Asian Development Bank
APCTT-UNESCAP	Asian and Pacific Centre for Transfer of Technology of the United Nations – Economic and Social Commission for Asia and the Pacific
AS	Australian Standard
AUD	Australian Dollar
AUIEG	Altai-Uliastai Interconnected Electricity Grid
COE	Cost of Electricity
CRIEG-	Central Regional Interconnected Electricity Grid
EIEG	Eastern Interconnected Electricity Grid
ERA	Energy Regulatory Authority (of Mongolia)
JICA	Japan International Cooperation Agency
HOMER	Energy Modelling Software for Hybrid Renewable Energy Systems
HPP	Hydropower plant
KfW	Kreditanstalt Für Wiederaufbau (Reconstruction Credit Institute)
kW	kilowatt
kWh	kilowatt-hour
LLC	Limited Liability Company
MONGOLBANK	The central bank of Mongolia
MNT	Mongolian National Currency (Tugruk)
MMR&E	Ministry of Mineral Resources and Energy
MTPP	Maximum Power Point Tracker
NASA	National Aeronautics and Space Administration
NPC	Net Present Cost
NREL	National Renewable Energy Laboratory (of the USA)
NREC	National Renewable Energy Corporation (of Mongolia)
PV	Photovoltaic

PREGA	Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement
RAPS	Remote Area Power Supply
RE	Renewable Energy
REAP	Renewable Energy and Rural Electricity Access Project
RES	Renewable Energy System
RETScreen	A clean energy project analysis software tool provided by the Government of Canada
TA	Technical Assistance
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
USA	United States of America
USAID	United States Agency of International Development
USD	United States Dollar
WIEG	Western Interconnected Electricity Grid
WA	Western Australia
WT	Wind turbine

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1. Introduction

Although, Mongolia has considerable potential for renewable energy, the share of renewable energy in electricity and heat generation is below 1%. (ERA, 2010) The Government of Mongolia (GOM) has focused on the use of renewable energy in decentralized and off-grid energy supply systems in remote areas of Mongolia. The Government Program on Renewable Energy and the Renewable Energy Law were approved in 2005 and 2007 respectively. According to the National Renewable Energy Program, the share of renewable energy in the country's energy generation industry is targeted to increase step by step, and 3-5% must be achieved in 2010 and 20-25% in 2020, (National Renewable Energy Program of Mongolia 2005).

Nowadays, governments of both developed and developing countries are progressively recognizing renewable energy technology as a viable option for the electrification of remote rural areas. In rural areas where grid access is technically impossible and financially infeasible, renewable energy systems can play an important role in power supply. Moreover, it is suitable at places that have no guaranteed diesel fuel supply due to extremely harsh climatic conditions, and people are not able to pay the high cost of electricity produced by using expensive diesel fuel. In Mongolian rural areas, especially for a soum (village or settled area) centre that is located more than 1000 kilometres from the capital city and over 500 kilometres from the Aimag (province) centres, the energy supply is vital for providing basic needs to people in that area.

To have a reliable electricity supply at rural soum centres is very important for securing the well-being of people living there. Soum centres are a kind of base administrative units in the countryside that plays an important role in providing social services to the people living in rural areas. Although, primary and secondary schools, and hospitals at soum centres have adequate qualified staff and relevant facilities, they are unable to use them for the designated purposes due to the lack of a reliable supply of electricity. As the level of such a basic social services has worsened at soum centres, more people—especially young people-- wish to move to urban areas or bigger towns where the quality of such services is at a satisfactory level, (PREGA-ADB 2006).

Thus, for reducing the migration of people to urban areas, the Government has to develop rural areas, especially by improving basic social services to the people living at rural soum centres. Reliable power supplies would be the basis for such development, but its cost should be affordable to local people, (PREGA-ADB 2006).

Figure 1: An example of small soum centre – Mandakh soum in Dornogovi Aimag, Mongolia (Google-Earth, 2011)

Figure 2: An example of a large soum centre – Bogd soum in Uvurkhangai Aimag (province), Mongolia (Google-Earth, 2011)

In consideration of fulfilling the general needs of people living in rural places and reducing the difference between urban and rural areas, a reliable and steady power supply to public organizations and households (also nomadic herders that come to get these social services at soum centres) is absolutely necessary as indicated below.

(a) **Health is an important issue for human life. Therefore, a reliable power supply would assure that hospitals at soum centres would be able to provide medical service in a safe manner at all times.** Each soum centre has a hospital that currently gets electricity from diesel generators that are operated for limited hours each day. Many hospitals do not possess petrol engine-driven generators for emergency use. If emergency surgery is required for a patient during the night-time, a hospital needs to have a reliable power supply at all times. Electricity is also necessary for keeping vaccines refrigerated as the Government continues to implement the national immunization program. Hospitals must clearly have a stable 24-hour power supply, (PREGA-ADB 2006).

(b) **Primary and secondary schools need to be supplied by electricity for educating children in rural areas.** Primary and secondary schools have been established at soum centres for children living at soum centres and for nomadic herders living in the vast countryside. Herders' children stay at school dormitories during their studies. The dormitories need to have stable electricity supply in order to provide a suitable living and learning environment. With a stable power supply, schools would be able to enrich the learning process through the operation of computers, projectors, printers, tape/CD players, VCD/DVD players, and TVs. The operation of those technologies would bring the rural schools up to the standards of the urban areas. Children staying in school dormitories use electricity mainly for light during their homework assignments. Lighting is also used in the kitchen, dining hall, toilets, and lounges. Some dormitories also have TVs and washing machines, (PREGA-ADB 2006).

(c) **Government's main goal for the country's regional development is to reduce the difference between the living conditions in urban areas and those in rural areas.** There is a huge difference between living conditions in big cities and those in rural soum centres in terms of basic social services (education, health, and others). The great difference is mainly due to unstable and unreliable power supply in rural areas. Due to difficult living conditions with a poor level of social services, many people living in rural areas are moving to aimag centres or big cities, which is causing more poverty and unemployment in urban areas. A reliable power supply is the basic necessity for maintaining human life and society at the required level and for conserving the traditional way of life. A reliable electricity supply system is required in order to achieve those objectives. Successful implementation of the renewable energy project is anticipated to help in promoting the creation of small and medium-sized entities to run a variety of enterprises, including the processing of dairy products, management of water supplies, and the making of agricultural and animal-origin products, (PREGA-ADB 2006).

2. Project Description and Methodology

2.1 Overview

There are 22 soum centres for which connection to the existing grid systems would require very high capital costs. These centres are either situated too far from the existing grid systems or located behind high mountain ranges with difficult conditions for the construction of transmission lines. The soum centres have diesel generators with a unit capacity of 65-100 kW but operate for only 4-5 hours each day. Diesel generator use has been affected by the significant increase in the price of diesel fuel (plus transportation cost) and by the fact that most of them are due for a major overhaul, which has been long delayed because of the lack of funds.

According to recent estimates, 22 soums, 1300 baghs (smallest administrative unit in the countryside), considerable numbers of frontier military units, and settlements, and 95,000 cattle-breeders are not served by the existing energy systems in Mongolia's rural areas.

The central and local government administrations struggle with the purchase of the necessary fuel for running existing diesel generators so that they operate for only 4-5 hours each day during the cold season, (A Master Plan for Energy Sector of Mongolia, 2003).

In the present situation the Government faces the following challenges in supplying the rural communities (InterSoums, Soums, Bags, Cattle-breeders) with power:

1. Scattered population of the rural communities,
2. Low repayment abilities of users,
3. Continental climate with harsh winters.

Due to these conditions, it is crucially important to develop and provide power supply facilities at low cost, which are transportable, safe, easy to maintain and suitable for a low population density. Mongolia, because of its geographical location and particular characteristics, has abundant renewable energy resources, which could be utilised to decrease the importation of fuel (petroleum products) and the outflow of much needed foreign currency. In addition, Mongolia can contribute to the protection of the environment. In particular, solar and wind energy are suitable for a decentralised supply and therefore very favourable for use in the country's rural areas.

In 2007 and 2008, the Government of Mongolia financed 12 projects out of the State budget that were aimed at creating renewable energy systems at soum centres in rural areas with difficult access to the grid. Most of the installed renewable energy systems had various technical and non-technical problems that resulted in their being shut down or in their operating in an unsustainable manner.

Historically, small-scale wind-solar hybrid systems (400W-8kW) were installed at hospitals, schools, dormitories, telecommunication offices of some soum centres of Mongolia where there had been no centralized renewable energy system that distributes electricity through a mini distribution network. More recently installed systems have a capacity ranging from 100 and 200 kW, and are actually larger than systems previously installed.

Experts from governmental agencies have often worked at installation sites and tried to fix problems and find possible solutions. Various field reports and introductory reports to the Ministry of Mineral Resource and Energy were developed. Currently, out of 12 systems, four systems have been completely shut down and eight systems are operating for a limited number of hours with a significant deficiency of energy supply, (Energy Authority of Mongolia 2010). A detailed study is required to investigate reasons for technical failure and unsustainable functioning of the established renewable energy systems. This research project will focus on issues related to the implementation of these projects.

2.2 Rationale

Operation and maintenance of these recently installed renewable energy systems are poor. Almost all of the renewable energy systems have had various technical faults and problems since their installation. All systems have been operating at low performance since their commissioning, (Energy Authority of Mongolia 2010).

Poor performance and technical failure of the installed renewable energy systems were also cited in the evaluation report made by the specialist of the Ministry of Mineral Resources and Energy of Mongolia. Many factors contributed to the poor result, However, it is necessary to investigate the main ones that have led to the technical faults and poor performance of the installed renewable energy systems. One of the main reasons might be design problems, probably due to the lack of experience and knowledge in this field. Therefore, investigation of design problems of renewable energy systems for creating sound and reliable renewable energy stand-alone systems in the future is important.

The Government of Mongolia intends to utilize renewable energy systems as an energy supply solution for rural soum centres in the future. Various international organizations and donor countries also have expressed their interest in implementing renewable energy projects in the rural areas of Mongolia in the future. Therefore, it is crucial to identify the drivers and barriers that have been experienced during implementation of previous renewable energy projects in order to learn possible causes and factors behind them.

This research project will investigate the technical faults that occurred at renewable energy systems, design problems of the RE systems, existing barriers and drivers in establishing small-scale renewable energy systems in rural areas of Mongolia. It will also search similar experiences in some countries with similar harsh climatic conditions and remote rural sites in order to learn possible appropriate solutions for a better outcome of projects to be implemented in the future. The research and study material also could be beneficial in terms of using case studies and reference material on technical and non-technical practical issues related to the use of small-scale renewable energy plants in rural areas of developing countries. There is, in fact, not much information or literature available about operational experience and technical faults of similar sized renewable energy systems (centralized type) installed in rural areas (village centres) around the world.

2.3 Project goal, objectives, and research question

In achieving the project goal for identifying and addressing drivers and barriers to renewable energy development in the rural electrification of Mongolia, real life information on 12 projects will be examined.

The types of renewable energy systems (solar-wind hybrid, solar PV only and wind only) and their locations can be seen from the list below:

1. Tseel in Gobi-Altai Aimag, (PV 30 kW+W120 kW) total 150 kW
2. Manlai in Umnugobi Aimag, (PV 30 kW+W120 kW) total 150 kW
3. Shinejinst in Bayankhongor Aimag, (PV 30 kW+W120 kW) total 150 kW
4. Bayan-Undur in Bayankhongor Aimag, (PV 30 kW+W120 kW) total 150 kW
5. Bayantsagaan in Bayankhongor Aimag, (PV 30 kW+W120 kW) total 150 kW
6. Matad in Dornod Aimag, (PV 30 kW+W90 kW) total 120 kW
7. Tsetseg in Khovd Aimag, 100 kW Solar PV system
8. Bugat in Govi-Altai Aimag, 160 kW Solar PV system

9. Khatanbulag in Dornogovi Aimag, 150 kW Wind system
10. Mandakh in Dornogobi Aimag, 80 kW Wind system
11. Sevrei in Umnugobi Aimag, 70 kW Wind system
12. Bogd in Uvurkhangai Aimag, 80 kW Wind system

2.4 Objectives

Objectives of the project are twofold: (1) To determine drivers and barriers based on real situations that show how the laws and programs dedicated to renewable energy development really act or are implemented in real life, and (2) To determine what important issues must be considered for installing renewable energy systems functioning in a sustainable way (technically, financially, and managerially) in remote rural areas.

2.5 Research questions

The kinds of questions I would like to answer are:

I. What lessons have been learned from the implementation of these renewable energy projects or from attempts to electrify rural soum centres by renewable energy?
II. What needs to be done or to be considered in the future in order to eliminate problems and remove barriers and enhance drivers related to renewable energy utilization?
III. What type of equipment or device is more reliable to function with fewer problems in harsh climatic conditions and what are the things that need to be addressed?

The key research question is:

What can be done to improve the viability of small-scale stand-alone renewable energy systems installed at centres of rural soums in Mongolia?

Installation of such types (solar-only, wind-only, renewable-only hybrid) of systems can be a real solution for reliable power supply at centres of rural soums. What issues are required to be considered to improve the situation or to implement a sound project in the future?

As part of this project, the information and facts in actual field reports, developed by the Energy Authority experts, will be studied in detail in order to learn ways for improving the viability and sustainability of these systems. Related aspects such as design, feasibility study, installation, operation, maintenance, management and ownership of the renewable energy systems will be considered. Real generation data obtained from installed renewable energy systems by the Energy Authority of Mongolia will be used for determining the actual generation of renewable energy systems and the status of electricity supply in rural soum centres.

By using theoretical and practical knowledge of designing the renewable energy systems some technical calculations will be done by using the technical specifications of the installed renewable energy devices. The purpose of these calculations is to determine the design problem and to evaluate the actual operational performance of installed renewable energy system in 12 centers of rural soums in Mongolia. Based on the methodology stated in Australian standard AS4509.2 "The design of renewable energy systems", back of the envelope calculations for the already installed renewable energy systems and the design calculation for the determined load will be carried out in order to assess the adequacy of the installed capacity of 12 renewable energy systems.

A detailed investigation and study will be carried out on the renewable energy system installed at centre of Mandakh soum, Dornogovi aimag, Mongolia. All detailed data of daily load, technical specification of installed wind, solar and diesel power systems, solar radiation, wind speed, ambient temperature data of the specific location will be used in simulation that will be done by using the HOMER software. Based on the result of simulation and optimization done by the HOMER software, more specific recommendations concerning the design and configuration of renewable energy system can be made. Advices for the best configuration in terms of reliable power supply and less cost option will be made.

Normal and reliable operation of these renewable energy plants is vital for ensuring the provision of basic social services to people living in these soum centres. Therefore, findings, results, and recommendations of this project can be useful for improving the performance of these systems. In addition, they can be used as a guideline and reference in implementation of similar kinds of projects in rural areas of Mongolia in the future for their sound and smooth development.

3. Background

3.1 Country information

3.1.1 *Geographical location*

Mongolia is a landlocked country located in the central part of Asia in the middle of two giant countries People's Republic of China and Russian Federation. Its exact geographical location is between the North latitudes 41°35" and 52°6" and East longitudes 87°47" and 119°57". Total land area of Mongolia is 1,564 million square kilometres. The total length of Mongolia's border is 8,114 km, of which 3,485 km (north of the country) borders with Russia and 4,677 km borders (around southern, eastern and western parts of the country) with People's Republic of China. Mongolia is 2,392 km from East to West, and 1,259 km from North to South. (National Statistical Office 2009, Main facts about the country)

Figure 3: Mongolia is shown in the map of the Asian Continent [Source: www.maps.com]

3.1.2 Population

The population of Mongolia was counted in 2011 and was 2.796 million people, an increase of 6.1% compared with 2007. Mongolia's average population density is 1.5 people per square kilometre. However, the density of population varies from 225 people/km^2 in the capital Ulaanbaatar to 0.80 people/km^2 in the Eastern part of the country and about 1.5 people/km^2 in the Khangai (mountainous area in the central and central-west part) region of the country. The population in urban areas is 1.733 million (62.0%) and the distribution of households is 60% in urban areas and 40% in rural areas. A typical Mongolian household has an average of four people. Life expectancy is 66 for a man and 70 for a woman.

3.1.3 Political and Administrative structure

When Mongolia announced its independence in 1924, it was named the People's Republic of Mongolia and had a communist regime until 1990. In 1990, Mongolia had a peaceful democratic revolution and the communist regime collapsed. Today, Mongolia has a democratic political structure. As for local administration, there are 21 Aimags (provinces) and 1 metropolis (Ulaanbaatar). Within the 21 Aimags there are 331 soums, which are the lowest units of provincial administration. The soums are composed of 1,453 baghs and Ulaanbaatar city has 9 districts and is subdivided in 117 khoroos, which are the lowest units of city administration. The existing local administrative system of Aimag and soum was established during the communist system. The local administrations are the base of a hierarchy topped by the state government. There are 21 Aimags (provinces) and under the Aimags there are soums ranging in number from 10 to 20. (Government of Mongolia 2011, Structure)

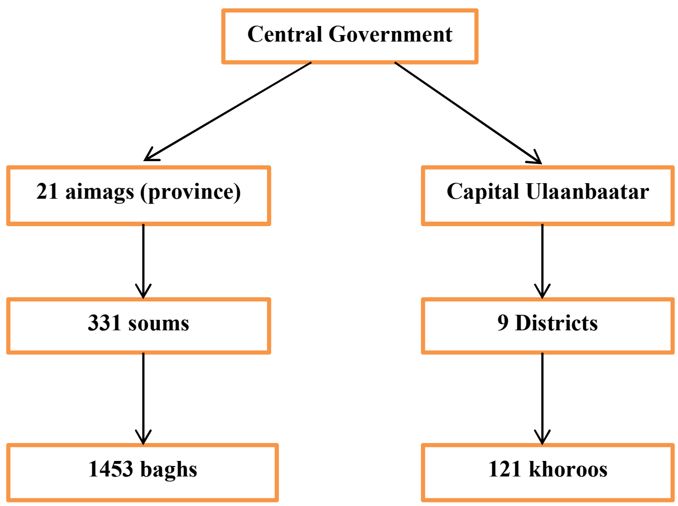


Figure 4: Chart of administrative structure of Mongolia

Aimags and soums have no effective fiscal power and the budget is set and approved by the central government. Management of this budget is made at Aimag and soum level. (Government of Mongolia 2011)

Table 1: Names of Aimags and their centres

No	Name of Aimag (province)	Name of the centre of Aimag
1	Arkhangai aimag	Tsetserleg
2	Bayan-Ulgii aimag	Ulgii
3	Bayankhongor aimag	Bayanhongor

4	Bulgan aimag	Bulgan
5	Darkhan-Uul aimag	Darkhan
6	Dornod aimag	Choibalsan
7	Dornogovi aimag	Sainshand
8	Dundgovi aimag	Mandalgovi
9	Zavhhan aimag	Uliastai
10	Govi-Altai aimag	Altai
11	Govi-Sumber aimag	Choir
12	Khentii aimag	Undurhaan
13	Khuvsgul aimag	Murun
14	Orkhon aimag	Erdenet
15	Sukhbaatar aimag	Baruun-Urt
16	Selenge aimag	Sukhbaatar
17	Khovd aimag	Khovd
18	Umnugovi aimag	Dalanzadgad
19	Uvurkhangai aimag	Arvaikheer
20	Tuv aimag	Zuunmod
21	Uvs aimag	Ulaangom

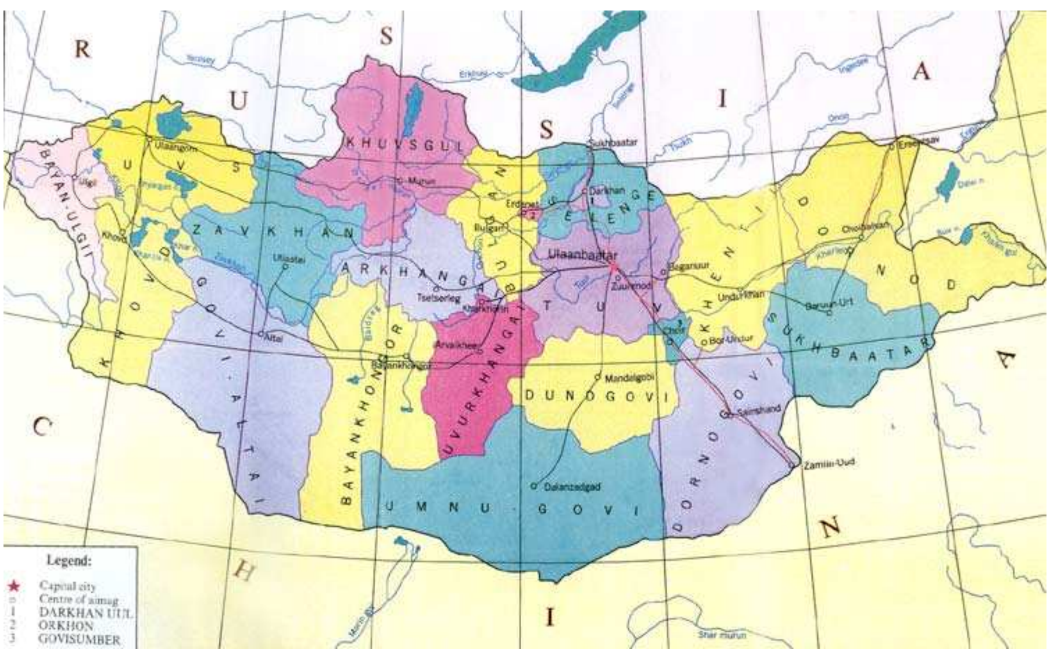


Figure 5: Administrative map of Mongolia (21 Aimags /provinces/ and their centres)

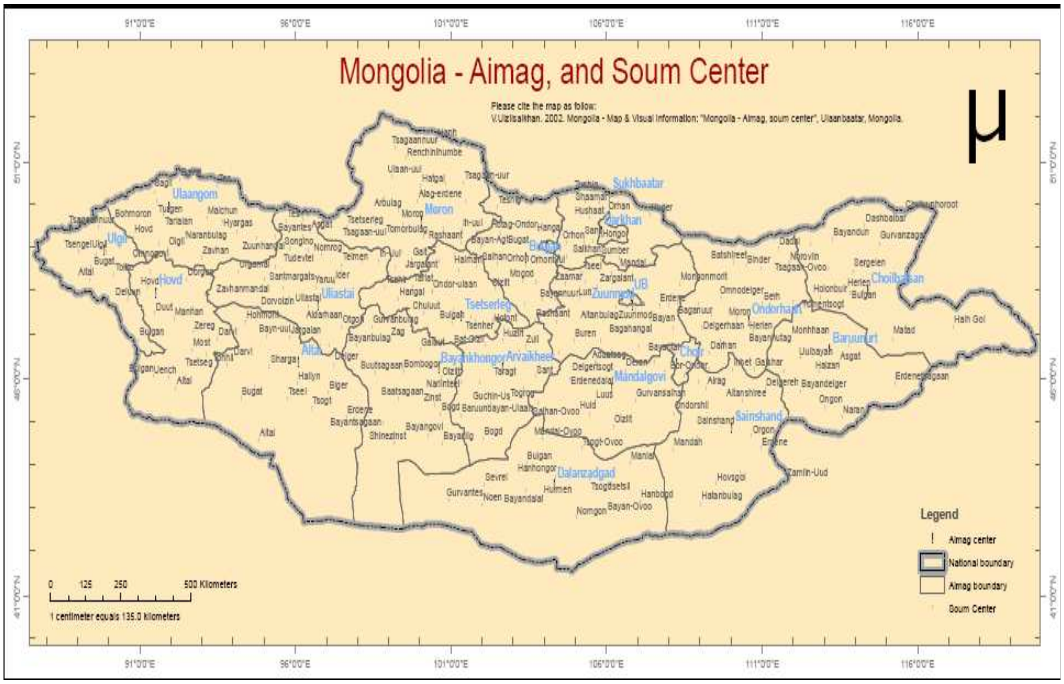


Figure 6: Administrative Map of Mongolia that shows 21 Aimags their centres, and 331 soum centres (Ulziisaikhan, 2002)

3.1.4 Climatic conditions

Mongolia's climate is harsh continental. The average altitude of the Mongolian plateau is about 1580 m above sea level. Ulaanbaatar city is the coldest capital in the world. Four seasons occur in Mongolia: Spring (March – May, average temperature 5^{o}C), Summer (June – August, average temperature 15^{o}C), Autumn (September – November, average temperature 7^{o}C), Winter (December – February, average temperature -19^{o}C)

Mountainous areas are mainly in the north, west, and central east parts of the country. The Gobi-Desert occupies most of the Southern, Southeastern and Southwestern parts of the country. Plain steppe occupies part of the east and southeast of the country. The distribution of precipitation is unequal both geographically and seasonally. Most of the precipitation (about 65-80%) occurs during the summer season. The northern region of the country receives most of the precipitation (about 400 mm yr^{-1}). Nevertheless, the southern Gobi desert and semi-arid plains receive less than 50 mm yr^{-1}. In most of the country, the average temperature falls below the freezing point between November and March and approximately to 0 degrees Celsius from April to October. In winter of most years, the lowest temperature during nights reaches -40 ^{o} C but during the summer, the extreme point can reach +40 ^{o} C in the Gobi desert area and around 33 ^{o} C in northern part of the country. The most windy months are March, April and May and the average wind speed is 2 – 5 m/sec. The winds usually travel from a west-to-northwest direction with speeds decreasing to 1 to 2 m/sec. During the winter season the country experiences heavy snowfall except its southern part. The average humidity is

50%. Weather conditions are very unstable and it is possible to experience four seasons just within a 24-hour period. The country periodically experiences strong dust (sand) and snow storms. The dry environment of the country results in dust storms with approximately 26 storms occurring each year. The dust is not toxic like cement or asbestos; it is just earth dust. With an average of 260 – 270 cloudless days per year, Mongolia is also known as the land of eternal blue sky, (National Agency for Meteorology in Ulaanbaatar 2011).

3.1.5 General power supply status in Mongolia

The energy sector of Mongolia consists of three interconnected electricity grids, two isolated grids and imports from Russia. Three interconnected electricity grids are (i) Central Regional Interconnected Electricity Grid (CRIEG) which supplies electricity to 14 Aimags and soums in their respective territories by linking major cities such as Ulaanbaatar, Darkhan, Erdenet, Baganuur, and Khutul; (ii) Eastern Interconnected Electricity Grid (EIEG) supplies electricity to Dornod and Sukhbaatar Aimag and their soums; (iii) Western Interconnected Electricity Grid (WIEG) supplies three western Aimags. The two isolated grids are (i) Dalanzadgad cogeneration plant and local grid, and Altai-Uliastai Interconnected Electricity Grid (AUIEG) which supplies to Zavkhan and Govi-Altai Aimags (which is connected to Taishir 12 MW and Bogdiin 2 MW Hydropower plants and diesel plants at centres of Aimags), (MMR&E 2011).

The Central Regional Interconnected Electricity Grid and Western Interconnected Electricity Grid are connected to the Russian Interconnected Electricity Grid and import electricity from Russia to provide systems' stability and supply the peak load. Only one company operates as a vertically integrated monopoly in the EIEG that consists of a cogeneration plant, transmission and distribution network. In the WIEG, there is one hydropower plant with 12 MW capacity, and a local transmission company with 3 local distribution companies in three Aimags, (MMR&E 2011).

There are five electricity generation companies, one transmission company, and four distribution companies in the CRIEG. The generation companies have 818.3 MW of installed capacity, of which 580 MW or 71% of the power is generated by cogeneration plant number 4 in Ulaanbaatar city. All thermal power plants are coal-fired cogeneration plants that also generate heat and supply to consumers through district heating networks in major cities in the cold season (from September 15 to May 15 in each year). Currently, 30 percent of the population lacks electricity and 43 percent is not connected to central heating grids. Heat is essential to survival, and the reliable supply of electricity is a key to improving the economy and daily lives of the people, (APCTT-UNESCAP 2007).

Table 2: Installed capacity of power plant in interconnected electricity grids (MMR&E 2010)

Power Plants	Installed Capacity (MW)	Available Capacity (MW)	Share	Boilers Capacity (MW the)	District Heating (MW the)	Share	Industrial Steam (MW the)
Power Plant #4	580*	468	70.8%	2,450	918	49%	29
Power Plant #3	140**	105	17.5%	1,448	562	30%	105
Power Plant #2	21.5	18	2.7%	80	43	2%	58
Darkhan	48	39	6%	477	210	11%	49
Erdenet	28.8	21	3.6%	318	140	7%	24
Subtotal CRIEG	**818.3**	**651**	**100%**	**4,773**	**1,873**	100%	**265**
EIEG	36	30	100%	397	130		22
WIEG (HPP)	12	12	100%				
AUIEG (HPP)	11	11	100%				
Dalandzadgad	6	5	100%	38	8		
Total	**883.3**	**650**		**5,208**	**2,011**		**287**

*- two 80MW turbine generators were modified to 100MW output in 2008 and 2009

**- installed capacity was reduced from 148 MW due to limitation of generator cooling system. Figure was confirmed by TPP#3. (Energy Regulatory Authority 2007)

Figure 7: Electrification Map of Mongolia (Mongolia's Integrated Energy System)

Note: Blue area – Central Energy System
Green area – Eastern Energy System
Yellow area – Dalanzadgad thermal power plant
Brown area – Altai-Uliastai Energy System
Pink area – Western Energy System

The voltage levels of transmission lines are 220 kV, 110 kV, 35 kV, 10 kV and 6 kV (Russian standard) and 0.4 kV for distribution line. Urban areas with buildings, have underground cables and most other areas are connected through the overhead lines. Coal is transported from two major coalmines by train to power plants (about 130 km and 220 km away from the capital city). Mongolia also has some oil deposits but it exports raw oil to China due absence of a refinery. Diesel fuel imported from Russian Federation is used for diesel generators and vehicles, locomotives with diesel engines.

3.1.6 Power supply in rural areas

The Government of Mongolia developed a “Program to improve electricity supply at soum centres” in 1999 and JICA developed the “Master Plan for Rural Energy Supply by Renewable Energy Sources” in 2000. According to these documents, the main policy is to connect soum centres to the centralized grids step-by-step. At the same time, the option to use indigenous renewable energy sources as widely as possible for the electricity supply of some soum centres is considered within the policy to be followed because the demand at the soum centres is limited and of the very scarce distribution of the soum centres in the vast territory. (JICA 2000)

Out of total 331 soum centres, some 309 have been connected to the CRIEG, EIEG and WIEG and two isolated grids up to date (MMR&E 2010).

Connected to the GRIEG:	224 Soum centres
Connected to the WIEG:	32 Soum centres
Connected to the EIEG:	26 Soum centres
Connected to the AUIEG:	19 Soum centres
Connected to the Dalanzadgad local grid:	8 Soum centres
Total connected:	309 Soum centres
Not connected:	22 Soum centres

(Mongolian Integrated Power Grid Program 2007)

In 2000, the number of off-grid soum centres was 172. Of these off-grid soums, 166 had received new generators under a Japanese grant aid program in 2001. Most soums have 2-3 generators, each with a capacity of around 60 kW - 100 kW. The total installed capacity of the above 172 off-grid soums was around 30 MW. Historically, all soums had communes (an association of herders that have a joint property and shared labour) that were formed in the 1950’s during the communist period. By that time, communes had created their own energy supply system in each soum centre – diesel generators with low voltage overhead distribution lines. Communes’ administrations were responsible for ownership, operation and maintenance of energy facilities. Diesel fuel supply was abundant during the communist period as it was imported from the former Soviet Union at a much cheaper price. Therefore, historically, people living in soum centres had 24 hour electricity supply during the cold season (September 15 to May 15) and 4-6 hours electricity supply during the warm season. In fact, by the 90's all diesel generators at 331 soum centres (manufactured in the former USSR and Czechoslovakia) were worn out and deteriorated. Under the grant aid from the Japanese government all diesel generators were replaced by new diesel generators (Mitsubishi, Hino, Denyo etc in 2000). The power supply situation improved greatly after the old diesel generators manufactured in Russia were replaced by new Japanese diesel generators. However, they operate only 3-5 hours each day in the winter season and there is no supply at all during the summer time because of the shortage of funds to purchase the diesel fuel (besides the diesel fuel price has increased significantly). The diesel plants in soum centres are operated less professionally and their service is very limited, (PREGA-ADB 2006).

3.1.7 Renewable energy applications in Mongolia

Most of the projects implemented in the renewable energy field were demonstration projects and they were financed by foreign donor organizations(system capacities were between 400W-8kW). Equipment mostly imported from abroad was mainly used in these projects. Experts, scientists and technicians of the Mongolian Academy of Sciences, and the Universities, undertook these projects. In fact, the skill, capability of these specialists, technicians and institutions are inadequate for sound implementation of projects. Therefore, it is necessary to build capacity by means of training, and transfer of renewable energy technologies through cooperation with international organizations, which have adequate experience in the renewable energy field. In addition, it is necessary to teach experts more about the design and economic assessment of renewable energy systems as well as the analysis of environmental impacts.

As Mongolia has a good solar energy resource, it can be utilized in generating electricity for electrification purposes in the countryside. In most rural areas the heating and cooking are based on biomass and fossil fuels. Government and Parliament have approved the "National Renewable Energy Program" and are planning to exploit the renewable energy resources. The 100,000 Solar Ger program was initiated by the Government of Mongolia in 2001 and has been implemented until 2009. Currently, over 104,000 Solar Home Systems are operating throughout the country. (APCTT-UNESCAP 2007) SHS systems (mainly imported ones) were sold to herders at discounted (provided by the Government as a subsidy) price and herders also were able to obtain soft loans from commercial banks.

Figure 8: 200kW PV-Diesel System in Noyon Soum, Umnugovi Aimag (KfW bank 2006)

There is already a commencing market for solar PV and wind generators. Low-cost PV systems and wind generators bought in China are used in the country, without (donor) assistance, mainly in rural areas, for use with lights, satellite TV's, and radios. Mongolian production of PV modules and wind generators also takes place.

UNDP studied the feasibility of a PV module manufacturing plant. In February 1998 a Photovoltaic Division of the Post and Telecommunications Authority of Mongolia established a state-of-the-art manufacturing facility for PV module assembly with assistance from the Nordic Development Fund. Its production capacity of 0.5 MW per year (for one shift) runs at the moment at 5–10% of capacity. This plant imports solar cells, related raw materials from abroad and produces 12, 24, 50W PV modules mono and polycrystalline modules are made for \$3.8 – 4.0/watt and are sold for about \$4.5/watt. Twenty-five radio repeater stations and many rural telecom offices (about 250) are supplied by stand-alone PV systems, which use PV panels produced in Mongolia. At present, more than 105,000 solar home systems reportedly are in use by herders for lighting, operating radio receivers, TV sets, satellite dishes and charging mobile phones. The PV systems have capacities in the range of 5 to 200Wp. Over 4500 wind generators reportedly also are in use in rural areas with capacities mainly between 50 and 200W.

No large-scale hydropower plant (HPP) has been developed yet in Mongolia. Projects for construction of big hydropower plants (Egiin Hydro Power Plant 220 MW and Orkhon Hydro Power Plant 100 MW) were stopped due to lack of funds. The small hydro power plants are run-off-river designs that provide electricity to neighbouring rural areas except during the winter. There are about 10 mini-hydropower plants that operate in the warm season (built on high mountain rivers located in the west and north of the country with capacity ranging from 160 – 900 kW). In some cases, they also provide electricity to centres of neighbouring soums.

In the Western Energy System region, under a loan provided by the Kuwait Fund a 11 MW hydropower plant was constructed at Ulaanboom gorge on the Taishir river. This hydropower plant supplies electricity to two Aimag centres and 19 soums. The Durgun hydropower plant with 12 MW capacity was constructed between 2004-2008 and connected to the Western Interconnected Electricity Grid. A private entity Newcom LLC is implementing a project to establish a 50 MW wind farm on an area located about 70 km south of Ulaanbaatar city. The wind farm is expected to be constructed from 2012 to 2014 and to be connected to the Central Interconnected Electricity Grid, (MMR&E 2011).

3.1.8 Renewable Energy Resources

Energy resources that have the potential to play an important role for energy balance of the country are solar, wind, hydro, geothermal and biomass energy. These resources are not yet included to the fullest extent in the energy production of Mongolia.

3.1.8.1 Solar Energy Resource

The total solar energy resources evaluated as annual solar radiation on the entire national territory has been calculated to potentially achieve $2.2*10^{12}$ kWh. The table below shows the potential solar energy (from Low (1200 kWh/m²/y) to High (1600 kWh/m²/y)) in four regions in Mongolia. Approximately 42% of the country lies within the 'Moderate-High' or 'High' solar energy regions.

Table 3: Solar energy resource of Mongolia (National Renewable Energy Corporation, 2006)

Region	Solar energy amount, kWh/m² / year	Area	
		km²	% of territory
Western	Up to 1200	109.900	7.0
Khangai	1200-1400	800.700	51.0
Central	1400-1600	392.500	25.0
Eastern	1600 and more	266.900	17.0

An example of the solar radiation data on an horizontal surface obtained from RETScreen (NASA's website) is shown in Table 4.

Table 4: Solar radiation data of Sainshand in Dornogovi Aimag, Mongolia (Retscreen 2011)

Sainshand	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
kWh/m^2/day	2.21	3.27	4.69	5.87	6.56	6.70	6.11	5.29	4.62	3.41	2.37	1.84
Ambient T^{o}C	-17.7	-12.5	-3.5	6.7	15.0	20.8	23.5	21.5	14.5	5.3	-6.7	-15.3

Data in the table shows strong seasonal changes with good resource level in summer and poor level of resource in winter.

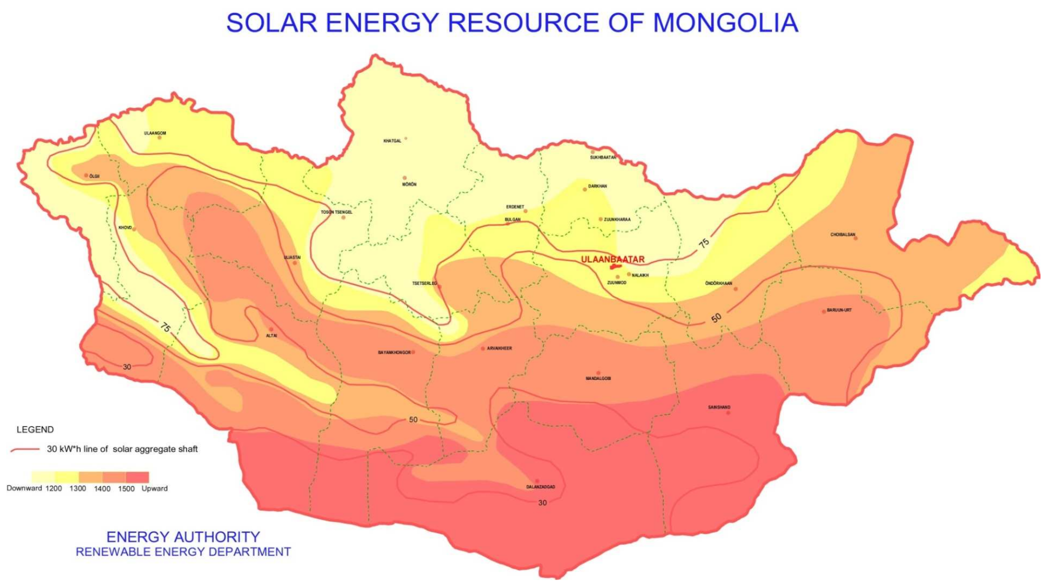


Figure 9: Annual global solar radiation, kWh/m2/year (Energy Authority of Mongolia, 2009)

More than 1600 kWh/m^2/year	- More than 4.38 kWh/m^2/day (annual average)
1600 kWh/m^2/year	- 4.38 kWh/m^2/day (annual average)
1500 kWh/m^2/year	- 4.10 kWh/m^2/day (annual average)
1400 kWh/m^2/year	- 3.83 kWh/m^2/day (annual average)
1300 kWh/m^2/year	- 3.56 kWh/m^2/day (annual average)
1200 kWh/m^2/year	- 3.28 kWh/m^2/day (annual average)
1100 kWh/m^2/year	- 3.01 kWh/m^2/day (annual average)

The intensity of solar energy declines from the southern to the northern part of the country with around a year more than 300 sunny days and sunlight hours are about 2600-3300 hours annually. As the country's geographical location is beyond Northern latitude 41, the advisable tilt angle for PV is latitude angle+15 degrees and fixed panels should face towards to south. Annual average ambient temperature is about 4.4^{o}C with lowest in the winter and highest in summer season.

3.1.8.2 Wind energy resource

Mongolia has a highly variable wind regime affected primarily by the mid-latitude westerly wind flow, which influences weather systems throughout the country. This westerly jet stream which runs several kilometres above sea level along with complex terrain, especially in western and central Mongolia, has major impacts on the distribution of wind resources in the country. The Aimags with the best resources include Umnugovi, and Sukhbaatar Aimags. The resource is directly related to topographical features making rolling plains typically good wind resource areas while more mountainous areas have significant wind resource variation. Exposed ridge-tops can have more than 600 W/m², influenced by the westerly jet stream, while valleys and plains can have wide variation. (NREL 2006)

In cooperation with the Renewable Energy Corporation and the National Institute of Meteorology of Mongolia, the National Renewable Energy Laboratory of the USA prepared a wind energy resource map for Mongolia. This map identifies six categories of potential wind power regions. According to this more general system of wind measurement, an area of more than 160,000 km² is convenient for installing high capacity wind power plants with a potential to connect them to the national electricity network. 10% or 56,500 km² of the Mongolian territory could be considered as areas with good wind energy resources. (National Renewable Energy Corporation 2006)

Adding on the regions with moderate wind energy resources, which are convenient for rural energy consumers or for the installation of low capacity wind generators, the area of windy regions sums up to 620,000 km², representing almost 40% of the total country.

Table 5: Wind energy potential of Mongolia (good to very good wind resource at 30 m height) (NREL 2006)

Cate-gory	Wind at 30 m height		Total area coverage		Total capacity MW	Energy to be produced GWh/year
	power W/m²	speed m/s	km²	%		
3	300-400	6.4-7.1	130,665	81.3	905,500	1,975,500
4	400-600	7.1-8.1	27,165	16.9	188,300	511,000
5	600-800	8.1-8.9	2,669	1.7	18,500	60,200
6	800-1000	8.9-9.6	142	0.1	1,000	3,400
Total			160,641	100.0	1,113,300	2,550,100

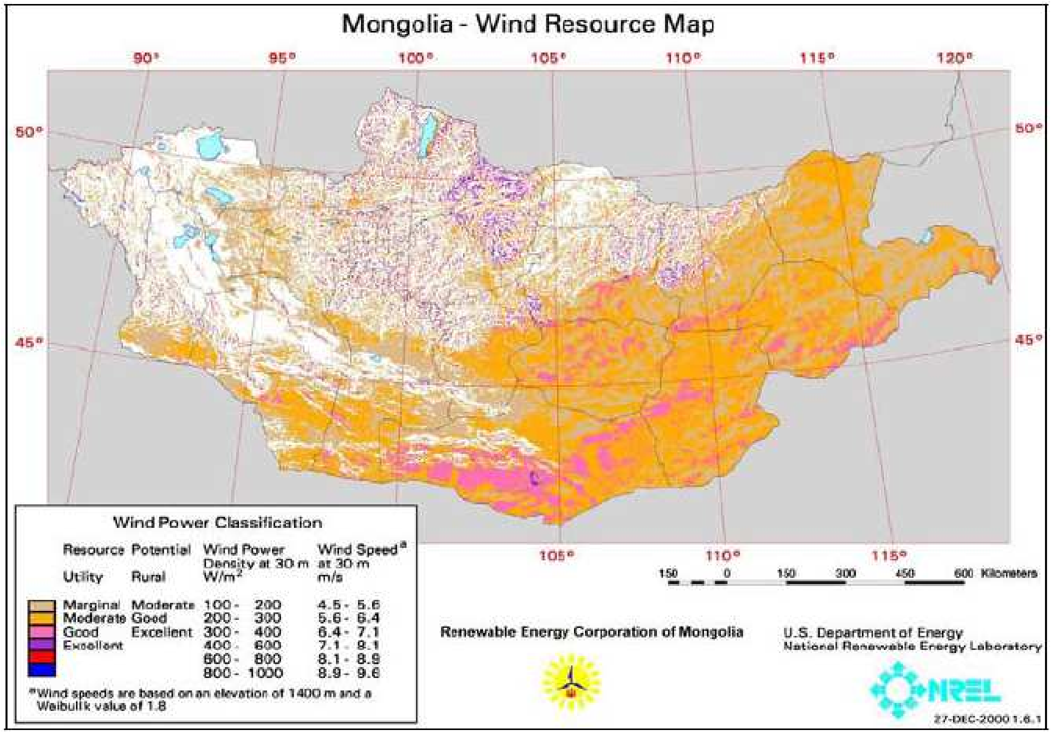


Figure 10: Wind resource map of Mongolia (NREL & NREC 2004)

3.1.8.3 Hydro energy resource

The average annual flow of Mongolia's 3,800 big and small rivers with a total length of 65,000km is estimated at 3,46 x 10^{10} m^3, providing a potential energy resource of 6,300MW or 56 x 10^7 kWh. The majority of the hydro energy resources are located in the mountainous areas in the western and northern regions. Pre- and Feasibility studies have been conducted for the construction of hydro power plants with capacities of 220MW at Egiin river in Khuvsugul Aimag, 100MW at Orkhon river in Bulgan Aimag. Many other sites have been identified for possible construction of small and medium sized hydro power stations to meet the energy needs of nearby soum centres. (Renewable Energy Corporation 2004)

The ADB Energy Supply Master Plan prepared in 2002 includes a summary of large and small hydropower projects, mostly in the western part of the country. The south and eastern Gobi regions do not have viable hydro potential for rural electrification. Many of the smaller hydro projects can operate only partially during the year because very low temperatures freeze rivers. Limitations in the runoff-river small hydropower operation for spring/summer months make these projects expensive and in many cases will require additional support either with diesel or other generation options.

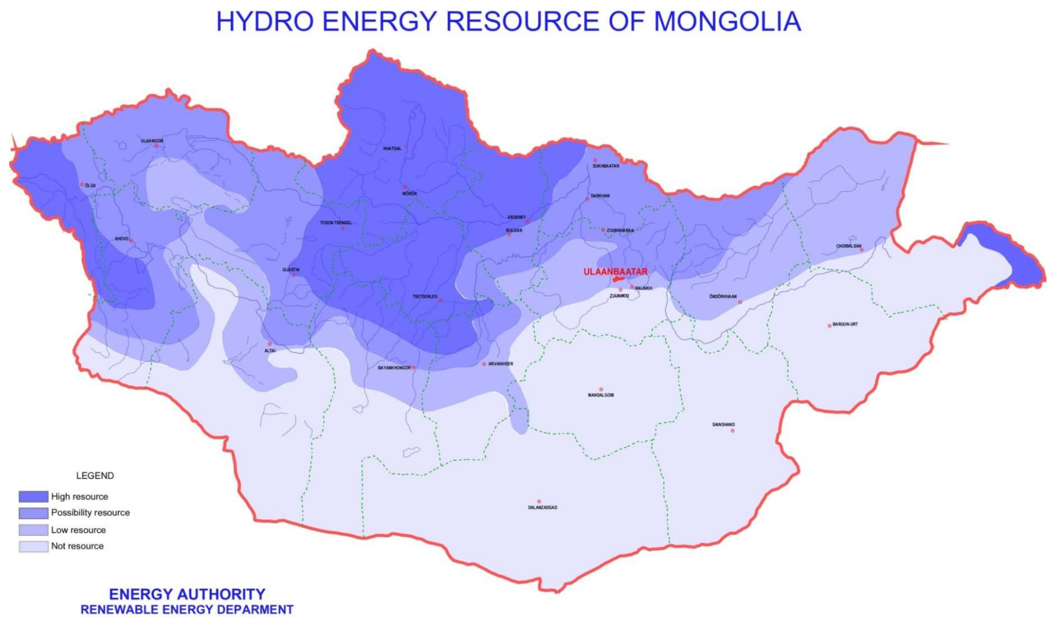


Figure 11: Hydro Energy Resources of Mongolia (Energy Authority of Mongolia, 2009)

3.1.8.4 Geothermal energy resource

Presently, there are 43 hot springs identified, but they have not been studied thoroughly. The hot springs are mostly located in mountainous areas of Altai, Khangai and Khentii mountain ridges, where no infrastructure is developed to make environmental and economical use of their energy potential.

3.1.8.5 Biomass

Since time immemorial, people have lived on Mongolian land and people still use biomass originating from livestock, such as dried dung from cows, horses, sheep and goats as fuel for cooking and heating. As of 2010, Mongolia counted 40.0 million heads of livestock, providing a considerable amount of biomass resources. Straw, wood, and shrubs are also collected and burned as fuel. Especially the saksaul species is preferred as firewood for its heat value and combustion performance. The massive use of saksaul (Mongolian name is Zag) and shrubs in the Gobi region is contributing to the destruction of the entire saksaul forests and increasing the desertification.

Table 6: Saksaul forest resources in selected Aimags (National Renewable Energy Corporation 2006)

Aimags	Saksaul forest (1000 ha)	Saksaul forest (1000 m$^{3)}$
Gobi-Altai	1925,7	522,3
Omnogovi	1173,9	541,8
Bayankhongor	477,8	113,1

Therefore, the efficient use of renewable energies like solar and wind could be one way to protect the endangered saksaul forest and shrubs.

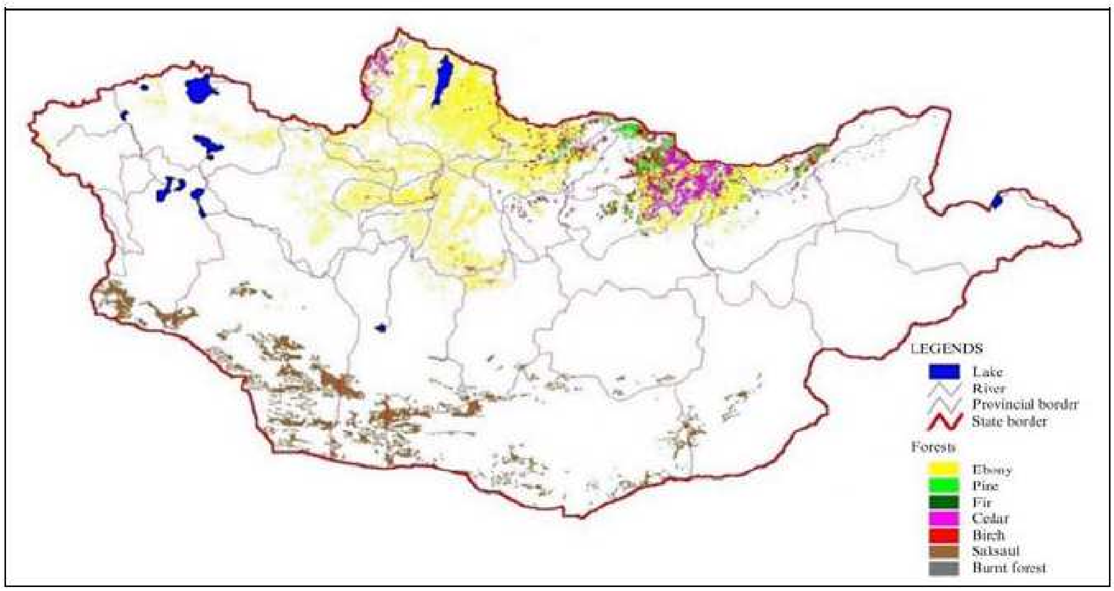
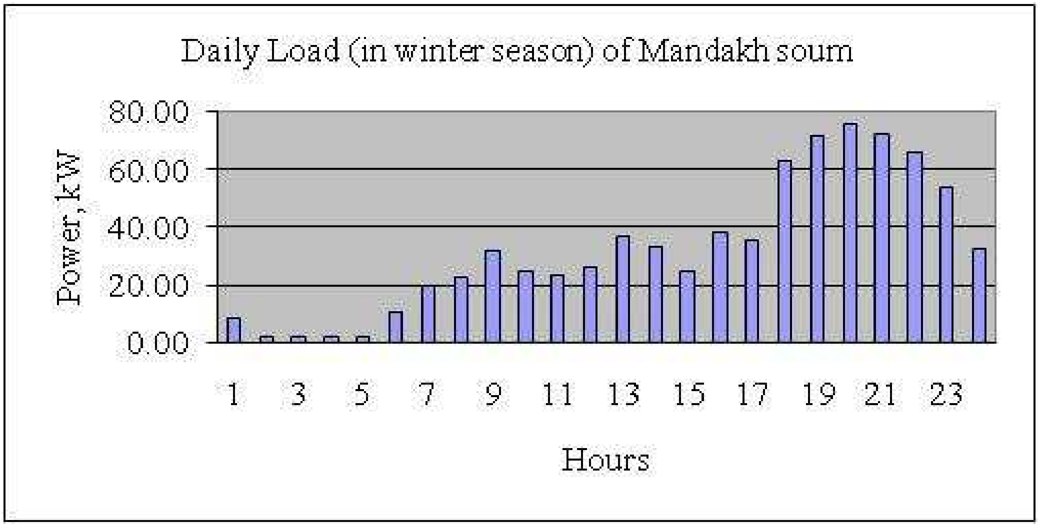


Figure 12: Renewable biomass resources (National Renewable Energy Centre 2005)

The heat-producing capacities of the dried cow dung, pellets, horse-dung, hardened dung and urine of sheep and goats differ greatly depending on both seasonal and regional characteristics. The minimum heat emission from dried cow dung is 10,800-13,300 kJ/kg, from horse-dung it is 8,800 kJ/kg, from pellets it is 16,700 kJ/kg and from the hardened dung and urine of sheep and goats it is 12,500-14,600 kJ/kg (Feasibility study for the energy production using biomass, TU Berlin 1997). Mongolians call the hardened dung and urine of sheep and goats accumulated over long period as "khurzun". Khurzun is a kind of compressed fuel that is renowned by nomadic people for its consistent heat emitting capacity.

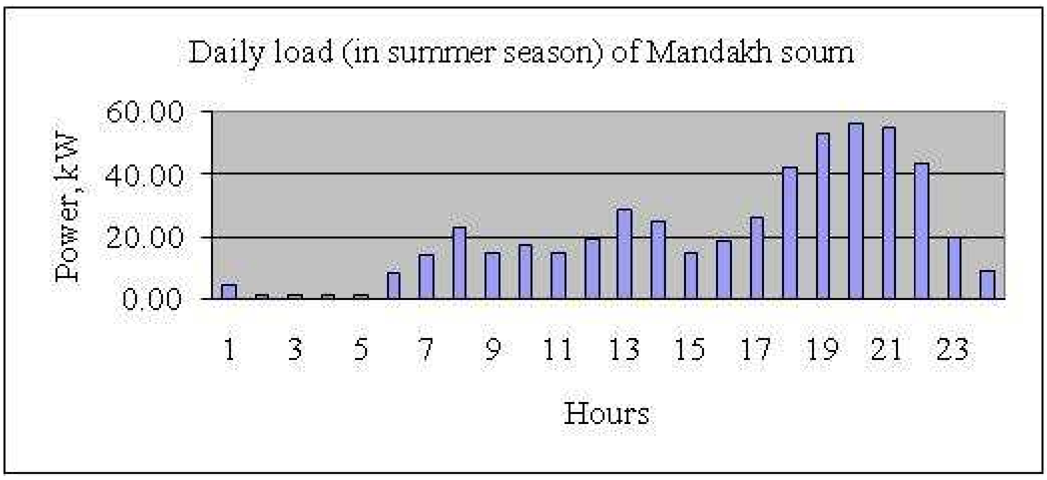
3.1.9 Typical demand pattern in rural soum centres in Mongolia

Population of soum centres ranges from 560 to 2500 depending on geographical location and living standards. Some soum centres close to Aimag centres have more residents than remote soum centres. Every soum centre has typical organizations such as the governor's office, primary and secondary schools, school dormitory, kindergarten, hospital, post office, veterinary, petrol station, cultural centre, heating boiler, and shops. Also some local small entities operate at soum centres such as a wool-washing plant, felt making plant, dairy product factory, bakery, woodwork factory, brick factory, and wheat flour factory, which use local raw materials in their production process. The number of people living at a soum centre varies seasonally due to the nomadic life style and habits of the people. The number of people living at a soum centre is different in winter and summer seasons, (ADB-TA3965 2007).



Daily load in winter season: Peak Load - 75 kW, Daily load - 772 kWh

Figure 13: Typical electricity consumption pattern Mandakh Soum in Dornogovi Aimag, Mongolia (Energy Authority 2007)



Daily load in summer season: Peak load – 55 kW, Daily load – 503 kWh

Figure 14: Typical electricity consumption pattern Mandakh Soum in Dornogovi Aimag, Mongolia (Energy Authority 2007)

The significant seasonal change in the number of people at a soum centre is mainly due to several reasons:

- people tend to have their vacation (annual leave) during summer (which is the pleasant season after a harsh winter)
- kindergarten, primary and secondary schools at soum centres do not work from the

middle of June to beginning September in each year

- Some herders with a small number of livestock stay at a soum centre during the winter and move to the countryside in order to stay in areas for foraging of their livestock.

Long days and short nights between May and October (warmer period), and short days and long nights between November and April (colder period) affect the electricity demand for lighting both inside and outside use. Also when the kindergarten, schools and their dormitories are in operation, this contributes to an increase in the load during the cold season. The peak load occurs usually between 5:00 pm and 10:00 pm. There is a very low load during the night time as there are no small factories that operate during the nighttime. The load increases a little bit in the morning between 6:00 am to 9:00 am when people get up and prepare to go to school and work. The load is little bit decreased during the daylight hours and tends to be at a certain level as organizations (schools, the kindergarten, governor's office, telecommunication office, petrol station etc) and entities (foods and commodities shops etc) are functioning. As organizations and entities work until 5:00-6:00 pm, that their contribution to the peak load is low. Only the secondary school sometimes organizes various events in the evening, but electricity is used mainly for lighting and for the operation of various electronic devices such as computer, printer and players.

At soum centres, electricity is mainly used for lighting of households and organizations. Almost all lights are incandescent bulbs. Households usually have a radio receiver (operated by battery) a TV set, video CD and DVD players, electric kettles and iron. Nowadays, some families have a refrigerator, a washing machine and a microwave heater. Organizations' main use of electricity is also for lighting. Some of them have desktop computers, and other electronic devices such as music systems, video projectors, photocopying machines, fax machines, fans and printers. School dormitories usually have a large washing machine, iron and TV. Hospitals have a refrigerator and an electric kettle. (ADB-TA3965 2007)

Typical electricity consumption of a household at a rural soum centre is about 100-150 kWh per month at soum centres connected to the grid and about 70-90 kWh at soum centres that operate diesel generators for limited hours. The low voltage distribution lines at soum centres have mostly deteriorated greatly due to the low level of maintenance and lack of required replacement of parts, (ADB-TA3965 2007). Due to this fact, the amount of loss in the distribution line is around 30-56% of the total distributed energy, (KfW Bank 2008). As soums' administrations own distribution lines and diesel generators, they commonly lack experience in management and maintenance of this infrastructure. Energy billing and revenue collection are a big issue at centres of rural soums. (World Bank 2006).

3.1.10 Government policy and strategy

The Government of Mongolia has restructured the energy sector, through enactment of a new energy law by the Parliament of Mongolia in 2001. The former Energy Authority, a vertically integrated monopoly, was unbundled and 18 new state-owned energy companies have been established. Energy activities were divided into different fields such as generator, transmission, distribution, supply, and dispatching. The implemented Energy Law provides a basic regulatory, inspection, and enforcement structure for generators, transmitters, distributors, suppliers, and consumers. It allows private and public sector involvement in the production of energy and establishes key policies in the areas of tariffs, energy efficiency, environmental quality, and safety, (PREGA-ADB 2006).

The Government has also focused on improving rural living conditions to reduce the increasing migration of rural population to cities, in particular to the capital Ulaanbaatar. This creates demands on schools, hospitals, and other social infrastructure services that cannot be met in the short to medium term. Government funds are no longer adequate to fully meet public infrastructure needs for health, education, and energy supply. The disparity between the reality and expectations based on past service levels in rural areas are contributing to the accelerated migration toward city centres, particularly to Ulaanbaatar. Poor electricity supply is a key contributor to the deterioration of these public services in rural areas.
Therefore, the Government of Mongolia has taken the following actions:

- Drafted the Energy Conservation Law in 2004 (but not approved yet)
- Drafted the National Renewable Energy Program in 2004 and approved by the Parliament in 2005
- Drafted the Renewable Energy Law in 2006 and approved by the Parliament in 2007
- Has been implementing a National Program called “100000 Solar Ger” since 2002

Although, the government had an ambitious goal to generate 15-20 % of the total electricity by renewable energy in 2010 in the National Renewable Energy Plan, it could not be attained due to lack of funds for implementation of large projects and unfavourable conditions (with high risks) for private investors. (USAID 2008) In the last 10 years, the Government of Mongolia has invested heavily in constructing many mini hydro power plants and hybrid renewable energy plants in rural areas. The Government is also promoting the development of renewable energy, both in utility and small-scale remote area power supply applications. (PREGA-ADB 2006).

4. Methodology (literature review, acquiring data and related information from Mongolia, analysis of the obtained data)

Due to the continuing performance problems of the existing systems, the Ministry of Fuel and Energy requested its implementing agency the Energy Authority, to carry out an investigation of the renewable energy systems. Consequently, some specialists of the Energy Authority have worked in each soum in 2008 and 2009 and have developed field reports based on actual facts determined during their investigations.

Information obtained from the Energy Authority of Mongolia will be investigated in detail. Related information such as photos, field reports, renewable energy systems' electricity generation data, and some technical drawings were obtained from the Energy Authority of Mongolia. Reports and introductory reports developed by experts from the Energy Authority include all related information such as the conclusion of turnkey contracts, development of designs, installation process, commissioning, operation, maintenance, and the technical and non-technical problems which occurred in these systems. Available information includes a detailed introductory report about each soum (load information) and the system installed (size of system and components) in it; also a general field report developed by specialists of the Energy Authority after they carried out site inspections at these 12 soum centres. Photos of renewable energy plants, (especially, photos of the broken and damaged parts) will be included as a proof of statements made in this paper. Detailed information (field report made after site visits at renewable energy plants and introduction about each soum) about these systems and soums (loads) can be seen in Appendix I. Electricity generation data (weekly for about a 6-month period) of these 12 renewable energy systems were also acquired from the Energy Authority and translated. A rough estimation of daily electricity generation is made based on the obtained data.

In this study I also consider electricity generation data of four other systems, namely Solar Systems which have been installed at the centre of Altai Soum of Gobi-Altai Aimag; 200 kW Solar (PV) system, Bayantooroi Bag of Tsogt Soum of Gobi-Altai Aimag; 100 kW Solar (PV) system, Urgamal Soum of Zavkhan Aimag; 150 kW Solar (PV) system, Durvuljin Soum of Zavkhan Aimag, 150 kW Solar (PV) system. Detailed information about the solar PV systems installed at centres of Bayantooroi Bagh of Tsogt Soum of Gobi-Altai Aimag (100 kW), Altai Soum of Gobi-Altai Aimag (200 kW), Urgamal Soum of Zavkhan Aimag (150 kW), and Durvuljin Soum of Zavkhan Aimag (150 kW) is not available as these system were installed as part of the Renewable Energy and Rural Electricity Access Project financed by the World Bank.

Materials related to the detailed case study into the Solar-Wind Hybrid Plant installed at Mandakh soum of Dornogovi Aimag, Mongolia were also obtained from the Energy Authority of Mongolia. This material includes, detailed information about Mandakh soum, and an introduction about the result of the feasibility study for the electrification of Mandakh soum, and a detailed daily load calculation for Mandakh soum both in winter and summer seasons. All original reports are in Mongolian and translated by the author of this paper, and will be attached as an appendix. Other relevant main information about Mongolia, its climate conditions, population, political structure, power systems etc was obtained from websites of relevant governmental organizations of Mongolia and was translated into English.

This dissertation will be focused on analysing the lessons have Supplier's learned during the establishment of these renewable-only hybrid systems, and will try to find out ways to improve the performance and reliability of these systems. In pursuit of this objective, the dissertation will include journal articles and reports about technical and non-technical problematic issues of similar types of renewable energy systems installed and operating in a similar climatic environment and rural areas in different countries, all of which materials will be studied in detail for possible causes of technical and non-technical problems.

5. Analysis of small scale RESs installed in rural soums' centres in Mongolia

5.1 Summary of technical issues

5.1.1 Status of currently installed RESs in rural soum centres

Summarized information of installed renewable energy systems at 12 soum centres is shown in the table below. It also has key information about loads at soum centres.

Table 7: Main information about components of installed renewable energy systems and loads

No	Name and location of installed Renewable Energy Systems	Type of components of the Renewable Energy Systems
1	**Tseel Soum of Gobi-Altai Aimag**, 150 kW Solar-Wind hybrid system  Summer daily load – 852 kWh Winter daily load – 910 kWh Winter daily peak load – 80 kW Annual load – 254,345 kWh	**Wind Turbines:** 120kW (6 units x 20kW, Anhua New Energy, made in China) **Solar System:** 30kW (PV module 230 pieces x 130W, type KC130GT made in Japan). **Inverter**: 1 unit x 132kVA (capacity), DC500/AC380V. **Battery**: 800Ah (2V) x 500 units. Made in China (It supplies electricity to 120 households and 8 public buildings and small shops.)
2	**Manlai Soum of Umnugovi Aimag,** 150 kW Solar-Wind Hybrid Power System  Summer daily load – 566 kWh Winter daily load – 897 kWh Winter daily peak load – 65 kW Annual load – 246,221 kWh	**Wind Turbines:** 120kW (12 units x 10kW, Tairu Windpower, made in China) **Solar System:** 30kW (PV module 166 pieces x 180W, Trina Solar Made in China). **Inverter**: 1 unit x 75kVA and 1 unit x 150kVA, Nanjin First Second Power Equipment Co. Made in China **Battery:** 1000Ah (2V) x 360 units Made in China. (It supplies 200 households and several public buildings and small shops.)

3	**Shinejinst Soum Bayankhongor Aimag,** 150 kW Solar-Wind Hybrid Power System  Summer daily load – 491 kWh Winter daily load – 607 kWh Winter daily peak load – 59 kW Annual load – 207,216 kWh	**Wind Turbines:** 90kW (12 units x 7.5kW, BWC Excel-R type, Bergey) Made in China **Solar System:** 30kW (PV module 180 pieces x 160W, 165W, 170W, Trina Solar). Made in China **Inverter**: 2 units x 60kVA, MTP-416F type. Made in China **Battery**: 1000Ah(2V) x 360 units Made in China **Control box:** SCP-240120 type. Made in China. (It supplies 120 households and several public buildings and small shops.)
4	**Bayan-Undur Soum, Bayankhongor Aimag,** 150 kW Solar-Wind-Diesel Hybrid Power System  Summer daily load – 730 kW Winter daily load – 820 kW Winter daily peak load – 83 kW Annual load – 267,842 kWh	**Wind Turbines:** 120kW (12 units x 10kW, BWC Excel-R type, Beijing Bergey Wind Power LLC.) Made in China **Solar System:** 30kW (PV module 180 pieces x 160W, 165W, 170W; Trina Solar). Made in China **Inverter**: 2 units x 60kVA), MTP-416F type, “Leonics” LLC Made in Thailand **Battery**: 1000Ah (2V) x360 pieces **Solar control box:** SCP-240120 type, “Leonics” LLC (Made in Thailand). (It supplies 150 households and 15 public buildings/entities and small shops.)
5	**Bayantsagaan Soum of Bayankhongor Aimag,** 150 kW Solar-Wind Hybrid Systems  Summer daily load - 625 kWh Winter daily load – 703 kWh	**Wind Turbines:** 120kW (12 units x 10kW, BWC Excel-R type, Beijing Bergey Wind Power Co.) Made in China **Solar System:** 30kW (PV module 180 pieces x 160W, 165W, 170W; Trina Solar). Made in China **Inverter**: 2 units x 60kVA), MTP-416F type, “Leonics” LLC (Made in Thailand)

	Winter daily peak load – 75 kW Annual load – 246,000 kWh	**Battery:** 1000Ah(2V) x 360 units. **Solar control box:** SCP-240120 type, "Leonics" Made in Thailand (It supplies 340 households and 20 public buildings/entities and small shops.)
6	**Matad Soum of Dornod Aimag,** 120 kW Solar-Wind Hybrid System  Summer daily load – 599 kWh Winter daily load – 700 kWh Winter daily peak load – 68 kW Annual load – 210,020 kWh	**Wind Turbines:** 90kW (9 units x 7.5 (10) kW, BWC Excel-R type, Beijing Bergey Wind Power Co.) and 29.7kW Made in China **Solar System:** (PV module 180 pieces x 160W, 165W, 170W; Trina Solar). Made in China **Inverter**:2 unit x 60kVA (40kVA), MTP-416F type, "Leonics" LLC. **Battery:**1000Ah (2V) x 360 units. **Solar control box:** SCP-240120 type, "Leonics" LLC. (It supplies 150 households and several public buildings/entities and small shops.)
7	**Bugat Soum of Gobi-Altai Aimag,** 140 kW Solar System  Summer daily load – 584 kWh Winter daily load – 725 kWh Winter daily peak load – 79 kW Annual load – 246,412 kWh	**Solar System:** 140kW (PV module 800 pieces x 175W; Trina Solar). **Inverter:** Two consisted of 60kVA & 100kVA, Made in Thailand by "Leonics" Co., Ltd. **Battery**: 1000Ah(2V) x 600 units (GFM type). Made in China **Charge controller** – 4 units, SCP-240120 type, "Leonics" LLC Made in Thailand. (It supplies 120 - 130 households and several public buildings/entities and small shops.)
8	**Tsetseg Soum of Hovd Aimag,** 100 kW Solar System 	**Solar System:** 100kW (PV module 570 pieces x 175W; Trina Solar, China). Made in China **Inverter:** 2 x 60kVA each, Thailand "Leonics" LLC. Thailand **Battery:** 1000Ah(2V) x 360 units. **Charge controller** – SCP-240120

	Summer daily load – 533 kWh Winter daily load – 713 kWh Winter daily peak load – 76 kW Annual load – 235,593 kWh	type, "Leonics" LLC. Thailand (It supplies 120 households and several public buildings/ entities and small shops.)
9	**Khatanbulag Soum of Dornogovi Aimag,** 150 kW Wind System  Summer daily load – 590 kWh Winter daily load – 780 kWh Winter daily peak load – 59 kW Annual load – 178,291 kWh	**Wind Turbines:** 150kW (15 units x 10kW wind turbine, Chendao, China). Made in China **Inverter:** Two 150kVA (480V), WZ150-1 type, Made in China). **Battery** 1000Ah (2V) x 240 units (Zibo city battery factory). Made in China (It supplies 140 households and 10 several public buildings/entities and small shops.)
10	**Mandakh Soum of Dornogovi Aimag,** 80 kW Wind System  Summer daily load – 503 kWh Winter daily load – 772 kWh Winter daily peak load – 75 kW Annual load – 250,913 kWh	**Wind Turbines**: 80kW (8 units x 10kW wind turbine, BBWC EXCEL R-240 type, Bergey, Made in China). **Inverter:** 100kVA, CPTT-180KVA type, Made in China). **Battery**: 1000Ah (2V) x 360 units (Shandong, Made in China). **Rectifier**: 3x380, 60kW, GDF-60KW, China. (It supplies 110 households and 10 several public buildings/entities and small shops.)
11	**Sevrei Soum of Umnugovi Aimag,** 80 kW Wind System 	**Wind Turbines:** 80kW (4 units x 20kW wind turbine, Anhua New Energy Development). Made in China **Inverter:** 100kVA, BNX500-31000 type, Made in China. **Battery:** 1200Ah (2V) x 250 units (Beijing Wei Xiang). Made in China

	Summer daily load - 644 kWh Winter daily load – 699 kWh Winter daily peak load – 62 kW Annual load – 228,502 kWh	**(**It supplies 110 households and 10 several public buildings/ entities and small shops.**)**
12	**Bogd Soum of Uvurkhangai Aimag,** 80 kW Wind System  Summer daily load -854 kWh Winter daily load – 900.53 kWh Winter daily peak load – 101 kW Annual load – 280,000 kWh	**Wind Turbines**: 80kW (4 units x 20kW wind turbine, Anhua New Energy Development Co.) Made in China. **Inverter:** 100kVA, BNX500-31000 type, Made in China. **Battery:** 1200Ah (2V) x 250 units (Beijing Wei Xiang). Made in China (It supplies 370 households and several public buildings/entities and small shops.)

Out of twelve systems, four systems have been shut down completely and two systems work normally (Solar PV only) and the remaining six systems (Solar-Wind Hybrid) often experience technical problems related to the wind turbines, battery bank, and the control system. Detailed information about each soum and installed renewable energy systems at the soum centres can be seen from Appendix I and II of this dissertation.

5.1.2 Selection of equipment and devices

Selection of equipment was made purely by the Contractors, which actually had no experience in installation, or operation of renewable energy devices. Contractors were not selected through competitive bidding but the Government made direct turnkey contracts with them. Contractors had imported almost all the equipment and devices from China, which is the closest market. However, when selecting equipment such as wind turbines, some of the Contractors did not consider the fact whether the selected equipment would be fit for normal operation in the extremely harsh conditions of Mongolia both in terms of climatic conditions such as high attitude, and low temperatures, but also in terms of extreme isolation and difficult installation conditions. Because of budget constraints, the Contractors had to buy cheap devices, which actually had low quality.

5.1.3 Assessment of RE resources

Out of the 12 soum centres, only at one soum centre namely at Mandakh soum in Dornogovi Aimag, where wind measurement devices installed and measurements were made for a period of 3 years. The assessment of wind energy resource was made appropriately in this case, and the expected electricity generation was calculated in advance based on the resource data and power curve of the wind turbine. However, for other renewable energy systems, no measuring devices such as pyranometer, anemometer, wind direction vane, ambient temperature sensor, and atmospheric pressure recorder were available in order to measure the actual level of available solar and wind energy resources. It should be noted that due to a sudden decision made by the Parliament and Government, there was not enough time to implement a resource measuring campaign; thus, solar and wind energy resources were not assessed in detail through measurement by installed measuring devices. A general solar radiation map of Mongolia was used for determination of available solar radiation at project sites. In fact, for 9 cases, the wind turbines were installed at places where no wind energy resource data was available. In other words, in those places it should have been a mandatory prerequisite to install the anemometer and wind vane devices and to take measurements for at least for a one year. Therefore, performance of some wind turbines is poor due to their installation with unknown wind data, especially in mountainous areas where the wind regime actually depends on the topography of that specific area.

5.1.4 Operation and Maintenance Status

In some soums, renewable energy systems can supply about 50% of the total daily demand in a day when solar and wind energy resources are available. In actual fact, most of them supply electricity to the users only for limited hours. It is a common factor that solar PV panels require less care during their operation, but in the Mongolian case during the winter time the snow fall on the panels must be cleaned after each snowfall otherwise the panels will not generate electricity. From the facts mentioned in field reports (Energy Authority 2010), it is clear that wind turbines require more maintenance and regular inspection for their safe and reliable operation. According to the report (Energy Authority 2010) developed by experts of the Energy Authority of Mongolia, it was emphasized that at almost all installations, the wind turbines had broken down during their operation when controllers were not working, or during strong winds. Real-time electricity generation data by these renewable energy hybrid plants can be seen in APPENDIX II of this dissertation or in a file entitled pec-624-Thesisc-tamk-30946612.xlsx.

5.1.5 Technical faults, design deficiency

Technical faults which occurred with renewable energy systems are summarized in the table below.

Table 8: Common technical problems, which, occurred at renewable energy hybrid systems during their operation

No	Names of RE hybrid systems	Types of common malfunction and technical problems									
		Wind turbine	**Unusual damage**	**Control systems (Controllers)**	**Battery failure**	**Charge and load regulator**	**Inverter**	**Control and power cables**	**Due to incorrect installation**	**Other damage**	**Lack of measuring devices**
1	**Tseel Soum's** 150 kW S-W hybrid system	✓		✓					✓		✓
2	**Manlai Soum's** 150 kW S-W hybrid System	✓		✓	✓	✓	✓	✓	✓	✓	
3	**Shinejinst Soum's** 150 kW S-W hybrid system	✓		✓	✓				✓		
4	**Bayan-Undur Soum's** 150 kW S-W hybrid systems	✓		✓		✓			✓		
5	**Bayantsagaan Soum's** 150 kW S-W hybrid system	✓		✓	✓	✓			✓		✓
6	**Matad Soum's** 120 kW Solar-Wind Hybrid Systems	✓		✓					✓		
7	**Bugat Soum's** 140 kW Solar System								✓		
8	**Tsetseg Soum's** 100 kW Solar System		✓	✓			✓		✓	✓	
9	**Khatanbulag Soum's** 150 kW Wind System	✓		✓		✓					
10	**Mandakh Soum's** 80 kW Wind System			✓	✓						
11	**Sevrei Soum's** 80 kW Wind System			✓	✓		✓			✓	✓
12	**Bogd Soum's** 80 kW Wind System	✓		✓	✓					✓	

A detailed explanation of the technical problems follows:

__5.1.5.1 Wind Turbine__

- ❖ Fall down during strong wind (Rotor, generator, together with supporting pole and guys were damaged) (Bayan-Undur, Bayantsagaan, Matad, Khatanbulag and Bogd soums).

Figure 15: A view of the fallen and broken wind turbine (Turbine #2 Bogd soum)

- ❖ Rotors and blades of wind turbines were damaged by strong wind – break, cracks, surfaces folded. At Bogd soum, a wind turbine’s blades developed a flaw during operation.

Figure 16: View of folded surface of blades, broken parts of blades, broken rotor – the shaft is broken and blades were damaged (Khatanbulag soum 2009).

Figure 17: View of the broken shaft and damaged rotor (Khatanbulag soum 2009)

- ❖ Brakes of wind turbines did not work or were not installed (in fact do not have brakes)

- ❖ Tower fixing guys (metal wire) were loose and not fixed correctly, in some cases the foundation for fixing guys had structural damage which was one of the causes for collapse of wind turbines

Figure 18: View of structural damage on guy fixing foundation (Khatanbulag soum)

Figure 19: View of the loose guy foundation and incorrect fixing. Three guys were tied to one foundation (Khatanbulag soum in Dornogovi Aimag and Manlai soum in Umnugovi Aimag).

- ❖ In some systems, there was no wind turbine braking and stopping system. (Bayan-Undur soum, Matad soum)
- ❖ Generator stator winding of one Wind Turbine was burnt when the controller was not working (Tseel soum)
- ❖ Wind Turbine # 1 at Bogd soum created unacceptable noise so that it could not be operated.
- ❖ Wind Turbine # 3 had a jamming problem, and once the rotor starts to work, it never stops as noted in the field report (Energy Authority 2010).
- ❖ Wind Turbine # 4 has a flaw in its blades.

5.1.5.2 Unusual damage

An interesting fact is that an animal which lives underground (in the Umnugovi Province which is the Gobi-Desert region) which called Zag's Rat has to cope with food deficiency and, they have eaten control cables (cables between the sensors and data acquisition system), and even power cables (sometimes they have caused a short circuits in 2008). Although, the Contractor restored the system by replacing all damaged cables, another similar instance of damage occurred due to Zag's Rats eating the cables in November 2009 (Manlai soum 2009). The glass of one PV module was damaged due to children playing or vandalism. (Shinejinst soum 2009).

5.1.5.3 Control system (Controllers)

- Electronic plates on wind turbine controller's electronic board were damaged, (Manlai soum, Khatanbulag soum).
- At 4 systems, data collection (logger) computer software was in Chinese language, and the previous logs could not be understood and were not recorded. Control computer was out of order, and it is unclear what kind of software was used. (Shinejinst soum, Bayan-Undur soum, Bayantsagaan soum, Matad soum,).
- No control system was installed. (Bugat soum).
- The control system was out of order. (Mandakh soum, Bogd soum).
- The control system was non-functional and software was damaged. (Tseel soum).

5.1.5.4 Battery failure

- Voltages were not detectable even in the battery elements, (Tseel soum).
- Batteries were out of order (Shinejinst soum - 200 units, Bayantsagaan soum - 21 units, Bugat soum – 2 units, Bogd soum – 37 units).
- Sulphate had formed in some batteries, and it smelt of sulphate in the battery room. (Khatanbulag soum).
- Batteries were installed in inappropriate environment or conditions. (Khatanbulag soum).
- Connection of batteries in series was made incorrectly. (Manlai soum).

Figure 20: View of the damaged batteries (Bugat soum)

Figure 21: View of batteries installed in inappropriate conditions or environment (Khatanbulag soum, Dornogovi Aimag).

5.1.5.5 Charge and load regulator (power conditioning)

At 2 installations, solar systems could not control the battery charging rates. (Bayan-Undur soum, Bayantsagaan soum).

5.1.5.6 Inverter

- ❖ Inverter was out of order (Sevrei soum, Bogd soum).
- ❖ Instead of installing an inverter with 150 kW capacity, two inverters with 60 kW capacity were installed. (Shinejinst soum, Bayan-Undur soum, Bayantsagaan soum, Matad soum).

5.1.5.7 Control and power cables

- ❖ At one system, control signal cables of wind turbines were damaged.

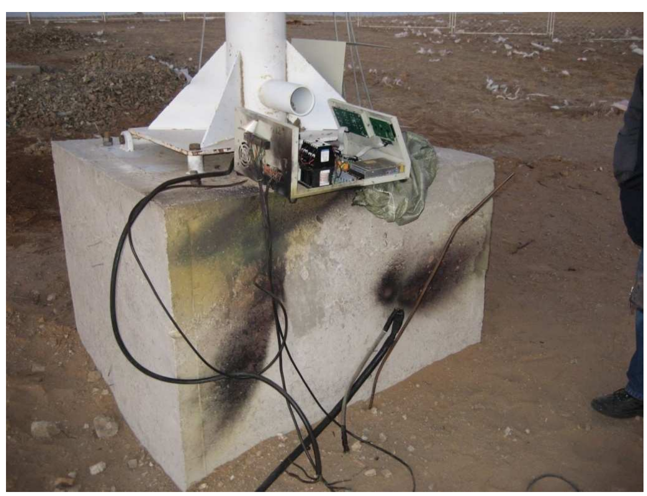


Figure 22: Electrical cables could not withstand the load, incorrect connection, and supplied charge regulator that did not meet with the requirements

- ❖ At one system, control cables connecting the controller and inverters to the logger computer were not installed. (Tsetseg soum).

5.1.5.8 Problems due to incorrect installation

- ❖ At one solar system, the components' connections were made incorrectly and needed to be changed. The Contractor was requested to rectify those defects. (Manlai soum).
- ❖ In 3 systems, there was insufficient distance (6 metres) between rows of solar panels , so that one was shadowing the other. (Tsetseg soum, Manlai soum, Bugat soum).

Figure 23: View of the incorrectly installed solar PV arrays (Tsetseg soum 2009)

- ❖ At four systems, hubs of wind turbines were not located (positioned) at the required height (elevation) (Matad soum, Shinejinst soum, Bayan-Undur soum, Bayantsagaan soum).
- ❖ Power and control cables are located in the earth without conduit. (Khatanbulag soum).

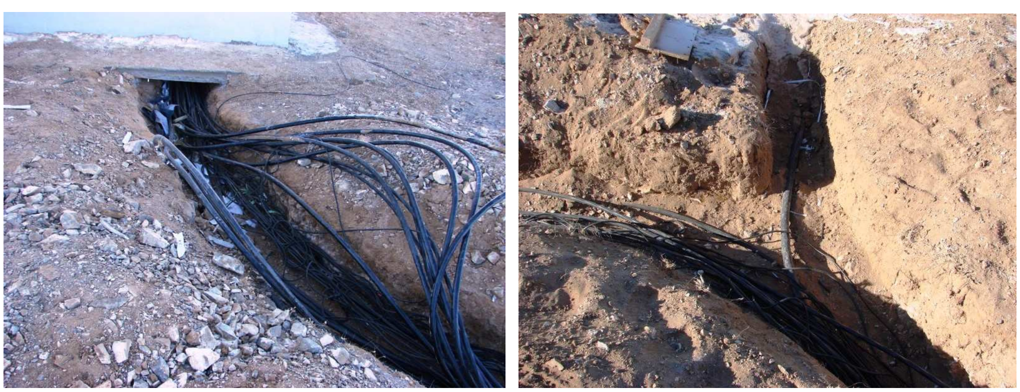


Figure 24: View of the cables lying out on the ground (Khatanbulag soum 2009)

- ❖ A dump load was not connected due to failure in the controller. (Bayan-Undur soum, Bayantsagaan soum).

5.1.5.9 Problems related to measuring devices

- In four systems, installed anemometers and wind direction measuring instruments had fallen down and become damaged. (Shinejinst soum, Bayan-Undur soum, Bayantsagaan soum, Matad soum).
- At nine systems, anemometers, wind direction vane, and ambient temperature measuring device were not installed, (Tseel soum, Shinejinst soum, Bayantsagaan soum, Bayan-Undur soum, Matad soum, Khatanbulag soum, Manlai soum, Sevrey soum, Bogd soum).
- Ammeter, voltmeter, wattmeter have not been installed on solar PV panel side at some installations. (Tseel soum, Manlai soum).
- Speed instrument (measurement of rotor rpm) of wind turbines was out of order. (Mandakh soum, Sevrei soum, Bogd soum).

5.1.6 Issues related to incorrect installation

As mentioned, the cause of some technical problems was incorrect installation. The common problem related to solar PV panels was that the distance between two arrays was too short and arrays were installed too closely. As a result, the array standing in front partly shadows the array standing behind it. In five systems, either the front or rear side arrays were removed or re-installed in a different position where they will not be shadowed by any object.

Figure 25: View of the shadowed solar PV panels (Manlai soum, 2009)

5.1.7 Things or parts need to be repaired or further improved

For 10 systems, it was recommended to repair and to improve the operation of wind turbines, and the hybrid system's control system.

- To install more Solar PV panels to secure the power supply and meet the power demand.

- For all systems that have solar PV arrays, the Maximum Power Point Tracker (MTPP) was not installed. For improving the performance of solar PV array, it is necessary to install a Maximum Power Point Tracker (MTPP).
- Solar-wind hybrid systems were not interconnected to the existing diesel generators. In order to provide a reliable back up for the renewable energy systems, it is necessary to connect existing diesel generators to the solar-wind hybrid plants and to install battery chargers that would enable battery charging from the diesel generators.
- According to the report (Energy Authority 2010) of the Energy Authority, solar PV panels with different unit capacity were interconnected in series for creation of arrays. For future projects, solar PV panels with the same unit capacity should be used in creating arrays so that installed capacity will be enough and technical characteristics would fit easily for setting of MPPT.
- Numerous problems have occurred in relation to the system design, component selection, equipment quality, management, and operation and maintenance. Those problems were considered to have been caused due to the lack of know-how (knowledge) in the system design and component selection, absence of awareness of energy efficiency, lack of use of international standards, inadequate supervision/examination of installation and commissioning, and insufficient operator training.

6. Non- technical issues

6.1 Initial financing

As mentioned before, the Government of Mongolia financed 12 renewable energy projects out of the State Budget and Fund for Development of Mongolia. Other renewable energy projects implemented before were funded by international financial organizations and donor countries.

6.2 Selection of potential contractors

According to the report of the Energy Authority of Mongolia, two main methods were used in the selection of contractors.

6.2.1 Through competitive bidding (tenders)

Competitive bids were announced in 2006 in accordance with the "Procurement Law of Mongolia" by utilizing state and local funds, and relevant evaluations were made. As a result, potential contractors were selected for the following renewable energy facilities:

- 30 kW Solar PV system installed at Tsetseg soum of Khovd Aimag
- 80 kW Wind only system installed at Mandakh soum of Dornogovi Aimag
- 70 kW Wind only system installed at Sevrei soum of Umnugovi Aimag
- 70 kW Wind only system installed at Bogd soum of Uvurkhangai Aimag

In fact, contractors selected through competitive tenders were more aware of the technical tasks because of addressing the tender by studying tasks stated in the tender document. In this case contractors had enough time to execute supply, installation and assembly works for equipment and devices within the contracted term and were more responsible in terms of fulfilling contractual obligations due to the fact that client withholds the performance guarantee (10% of total contract price) and takes it if the contractor fails to perform its contractual obligation. However, some selected contractors (a pure political decision by the minister) did not have any experience of installing and commissioning any size of renewable energy systems, (Energy Authority 2010).

6.2.2 Direct contract award

The Great State Hural (Parliament) made an amendment to the "Procurement Law of Mongolia by utilizing State and Local funds" on February 6, 2007. A new clause was added to the law which stated that "… if the size of investment for construction of roads, railway, and energy projects is equal to or exceeds the currently available capacity of local entities which are specialized in these fields, the Government is entitled to choose contractors directly based on standard market price…". The Government of Mongolia approved a list of projects and programs, which should be implemented by using the direct contract award method in accordance with its resolution # 50, dated March 7, 2007. In this list, all renewable energy projects that were planned to be financed out of the "Mongolian Development Fund" were included. Based on resolution # 50 of the Government of Mongolia, the Ministry of Fuel and Energy of Mongolia selected contractors for execution of these works by issuing its order #25 on March 26, 2007. Contracts (turn-key) were made with all selected contractors on March 26, 2007 (Energy Authority of Mongolia 2009).

The following systems were installed under the direct contract award method:

- 150 kW Solar-Wind hybrid system installed at Tseel soum of Govi-Altai Aimag
- 150 kW Solar-Wind hybrid system installed at Manlai soum of Umnugovi Aimag
- 150 kW Solar-Wind hybrid system installed at Shinejinst soum of Bayankhongor Aimag
- 150 kW Solar-Wind hybrid system installed at Bayan-Undur soum of Bayankhongor Aimag
- 150 kW Solar-Wind hybrid system installed at Bayantsagaan soum of Bayankhongor Aimag
- 120 kW Solar-Wind hybrid system installed at Matad soum of Dornod Aimag
- 70 kW Solar PV system installed at Tsetseg soum of Khovd Aimag
- 60 kW and 80 kW Solar PV systems installed at Bugat soum of Govi-Altai Aimag
- 150 kW Wind only system installed at Khatanbulag soum of Dornogovi Aimag

The result is that inexperienced non-professional Contractors (might be a kind of bribery and corruption related actions taken by politicians) have done poor quality installation work, did not organize sufficient training, and did not provide satisfactory operation and maintenance manuals, (Energy Authority of Mongolia, 2010).

6.3 Ownership

Although soum administrations are in charge of managing the renewable energy systems, actually physical assets (properties) are considered as State Property. Thus, local governments at soum centres have no responsibility for maintaining and taking care of the installed system. As a result, soum administrations have no feeling of ownership and lack of management prevails mainly due to this factor. In all reports about the installed renewable energy systems there was mentioned the necessity of solving the ownership issue concretely by raising issues with the State Property Committee which has the authority to take a final decision, (Energy Authority of Mongolia, 2010).

6.4 Management

A soum administration has few officers, and they are primarily responsible for civil service and administrative issues. However, the soum administration has to be responsible for the management of renewable energy systems and sales revenue collection at the soum centre. Operators are usually tractor drivers who used to work as diesel operators before, and have limited knowledge of electrical theory and devices. Because of the low level of fixed tariff, some soums even have only one person in charge for operation, maintenance, and sales revenue collection tasks. There are no organizations available to provide service and maintenance for local overhead distribution lines (0.4 kV) at soum centres. Therefore, operation, maintenance, and sales revenue collection are at a very poor level. Some governors even fired pre-trained and prepared operators and appointed untrained people (in fact, they appointed their relatives and friends) as operators (Energy Authority of Mongolia, 2010).

6.5 Losses in the distribution lines

It should be noted that the technical condition of the existing low voltage distribution networks had deteriorated significantly (since the transition from centrally planned economy into the market oriented economy started in 1990) due to poor maintenance and replacement of parts. Thus, energy losses in these distribution networks were around 25-35% of the total electricity distribution. Electricity theft is at a high level at soum centres, as people are able to connect their homes directly from the bare aluminium conductors of overhead distribution lines (World Bank, 2005). Therefore, in order to reduce distribution loss and risk of faults due to poor mini-grid condition, low voltage (0.4 kV) overhead distribution grids in these (12 soums with RE projects implemented by the Government of Mongolia +4 soums with RE project implemented by the World Bank.) soum centres were improved and rehabilitated in 2008, 2009, and 2010 (improvement of distribution lines by laying out cables with insulation, and replacement of transformers, wooden poles and concrete supports, and in some cases installation of electricity meters at every consumer) under the "Renewable Energy and Rural Electricity Access Project" (REAP) of the World Bank. Conditions improved significantly after implementation of the project. Particularly, the technical and commercial loss in the electricity distribution network has reduced as the result of the project.

6.6 Tariff and revenue collection mechanisms

These renewable energy systems generate electricity using wind and/or solar technologies and have brought significant reductions in operating costs compared to the previous power supply

by means of diesel generators alone. People living in soum centres pay a fixed payment for electricity usage due to lack of meters installed at each household. Thus, consumers do not have any motivation to consume electricity in an efficient way or to save energy.
Information obtained from the Energy Authority is shown Table 9.

Table 9: Electricity tariff status of renewable energy systems (Energy Authority of Mongolia 2010)

No	Name and location of installed RE systems	Tariffs for electricity supplied by the Renewable Energy Hybrid systems
1	**Tseel Soum of Gobi-Altai Aimag**, 150 kW Solar-Wind hybrid system	Each household pays 8,000 MNT (5.5AUD/6.0USD) per month. The bills collected could not fully cover operation and maintenance cost and totally spent for diesel fuel purchasing and workers' salaries.
2	**Manlai Soum Umnugovi Aimag,** 150 kW Solar-Wind Hybrid System	In the report it was mentioned the necessity to set the tariff.
3	**Shinejinst Soum Bayankhongor Aimag,** 150 kW Solar-Wind Hybrid Power System	Since the plant was put into operation about 8.0 million MNT (5,517AUD/5,926USD) was collected as sales revenue by May 2009 and accrued 1.5 million MNT (1,034AUD/1,111 USD). Each household pays 10000.0 MNT (6.9AUD/7.4 USD) per month.
4	**Bayan-Undur Soum, Bayankhongor Aimag,** 150 kW Solar-Wind Hybrid Systems	Since the plant was put into operation its sales revenue acquired and expenses spent are equal. Each household pays 3000.0 MNT (2.06AUD/2.22USD) per month.
5	**Bayantsagaan Soum of Bayankhongor Aimag,** 150 kW Solar-Wind Hybrid System	In the report it was mentioned the necessity to set the tariff. Currently the soum's administration is charging 5,000 (3.45AUD/3.70USD) MNT per month from each household and 7,000 MNT (4.82 AUD/5.18 USD) per month from each entity.
6	**Matad Soum of Dornod Aimag,** 120 kW Solar-Wind Hybrid System	The Regulatory Board of Dornod Aimag has not set a tariff for this system yet. In the report it was mentioned the necessity to set the tariff.
7	**Bugat Soum of Gobi-Altai Aimag,** 140 kW Solar System	In the report it was mentioned the necessity to set the tariff.
8	**Tsetseg Soum of Hovd Aimag,** 100 kW Solar System	Ger household pays 5000 MNT (3.45AUD/3.70USD) per month Apartment household pays 6000 MNT (4.13AUD/4.44USD) per month

		Retired people pay 3000 MNT (2.06AUD/2.22USD) per month By April 2009 the plant had accrued 2.5 million MNT (1,724AUD/1,852 USD).
9	**Khatanbulag Soum of Dornogovi Aimag,** 150 kW Wind System	Tariff was not set and approved by the beginning of 2010. In the report it was mentioned the necessity to set tariff.
10	**Mandakh Soum of Dornogovi Aimag,** 80 kW Wind System	No tariff was set by Dornogovi Aimag's Regulatory Board by February 2010. In the report it was mentioned the necessity to set tariff.
11	**Sevrei Soum of Umnugovi Aimag,** 80 kW Wind System	No information available. The Plant was shut down after the soum centre connected to the grid.
12	**Bogd Soum of Uvurkhangai Aimag,** 80 kW Wind System	No tariff was set by February 2010. The old tariff – 120 MNT/kWh (8.2 cents AUD/kWh or 8.8 cents USD/kWh) was used for new wind plant.

Following exchange rates were used:
(1AUD = 1450, 1USD = 1350 October 4, 2011 Mongolbank)

Cheap electricity tariffs have bad consequences, such as low salary for operators, lack of funds for regular maintenance of wind turbines and batteries, and lack of funds for replacement of some components after their lifetime finishes. It is stated in the Renewable Energy Law of Mongolia that the tariff for electricity generated by stand-alone solar PV systems should be US$ 0.2-0.3 per kWh and the tariff for electricity generated by stand-alone wind systems should be US$ 0.10-0.15 per kWh. Tariffs must be approved by regulatory boards of Aimags but until today, none of the Aimags' regulatory boards have approved this tariff. The problem is that the clause of the Renewable Energy Law concerning the Renewable Energy Fund has not been implemented at all. It actually depends on implementation of a separate law called "Law on Government's Special Funds" which has to provide required funds to cover the difference between the regular retail tariff (about 0.05-0.06 US$/kWh) and the tariff of renewable energy generators. The Government of Mongolia has not provided any funds into the "Renewable Energy Fund" since the Law on Government's Special Funds and Renewable Energy Law of Mongolia came into force in 2006 and 2007 respectively. In order to show the low affordability of people living at soum centres the following two sections with detailed information have been prepared.

6.6.1 Income of people in rural areas

According to a survey that was conducted by the National Statistical Office of Mongolia in the last year, the income of people living in rural areas was estimated approximately. (NSO 2010)

In rural areas the salary level for civil servants and private company workers was around 108,000 – 200,000 MNT (88-162 AUD) monthly in 2010. In the category of civil servant the following common jobs were included: soum's governor, workers of soum governor's administration, bagh's governor, a constable, and staff of the schools (primary, secondary), operator of heating boiler, operator of diesel power plant, various drivers etc. Herders do not receive a regular salary or wage but they have their own livestock which they got through privatization between 1990 and 1998. Herders sell domestic animals and products of domestic animal origin.

Table 10: Value of herders products (an exchange rate of 1AUD=1220MNT was used the exchange rate announced by Mongolbank July 5, 2008)

No	Animal Products	Measuring unit	Average sale price expressed by MNT	Prices expressed by AUD
1	A year-old sheep	Piece	65000	53
2	A sheep	Piece	100000 - 115000	80 - 94
3	Skin of a sheep	Piece	6000	5
4	Cattle or cow	Piece	220000 - 350000	180 - 287
5	Skin of cattle	Piece	20000	16
6	Meat of sheep	kilogram	2500	2.1
7	Goat cashmere	kilogram	35000	29
8	Beef	kilogram	3000	2.5
9	Cow milk	litre	600	0.5
10	Cow milk cream	kilogram	1300	1.06
11	Clarified butter	kilogram	1700	1.4
12	Yogurt (bonnyclabber)	litre	600	0.5
13	Curds from sour milk	kilogram	700	0.57
14	Dried curds	kilogram	900	0.74
15	Cheese	kilogram	1500	1.23

Prices shown above are the average prices for which herders sell these items. Thus, they cannot be considered as a regular income per month. Incomes are different in each season. For instance, herders do not regularly sell living livestock, and some products of animal origin can be made available in only some specific periods of a year. Therefore, herders' have no fixed regular income. Only a few herders have many livestock. However, most of the herders are not wealthy and have about 30-90 livestock on average. Thus, herders' affordability mainly depends on the number of livestock they own, and the number of activities they do. Their income is not guaranteed, since livestock can be lost due to a "dzud" disaster in which all pastures are covered by heavy snowfall, strengthened with a very cold temperature. This causes scarcity of food and weakness for both humans and livestock. In fact, both for the people living at soum centres and for the herders, household income is often supplemented by a second regular income such as a pension for elders, child allowance money, support for mothers with many children, and allowance for people with disability, etc. About 50% of a soum's households were herders, 25% of householders worked in the civil service, 8% of householders worked at private companies or are retired. According to the survey, the average household income ranges from 1,296,000 – 2,400,000 depending on geographical location (for instance some soums close to Aimag centres or big cities or railways or paved roads, or borders, or having access to the centralized grid, have more advantages), and the size of soum.

6.6.2 Expenditure of people in rural areas

Herders and people living at soum centres need to buy some basic necessities (food, clothes, energy etc). They also need to pay the tuition fees (also related travel and living cost) of their children who are studying at universities in urban areas. People also spend some of their income for buying essential items such as batteries for radio receivers and flashlights, candles for lighting purposes, petroleum for their motorbike or car and diesel or petrol for small petrol (either gasoline or diesel fuel) engine driven generators etc. People living in soum centres spend part of their income for paying a fixed electricity bill. Everyone has to spend something for preparing their children's school uniform, books and stationery items. Part of the income is deducted as tax income by the state but it depends on the amount of the income. Commonly, people living in soum centres spend about 13% of their total household income for buying solid fuels such as firewood, dung, and coal (ADB-TA3965 2007). The aforementioned fuels are used for heating and cooking purpose. Total energy expenditure accords for 25% of household expenditure, which is a significant cost (ADB-TA3965 2007). Various kinds of other expenses arise due to different situations and necessities; however, people are able to cover such expenditure occasionally, according to the affordability. In fact, expenditure often exceeds the regular income so that people have to borrow money from others or banks until their next income arrives (ADB-TA3965 2007).

6.7 Technology transfer

Technology transfer has not occurred successfully. Operators do not have enough knowledge and skills about how to operate and maintain installed renewable energy systems properly. No general awareness training was provided to the public so that people living at soum centres have no understanding about the operational features of renewable energy systems nor knowledge about how to adjust their electricity consumption when renewable energy resources (solar and wind) are not available for some period. Overloading of the renewable energy system is a common phenomenon at soum centres due to lack of implementation of energy efficiency measures before installation of renewable energy systems. Local community stakeholders were not invited to participate in the project implementation process as the contractors for the project commenced their installations.

6.8 Training and provision of technical service and support

Training for the operators was not organized at a satisfactory level so that in some cases, faults occurred due to wrong action taken by the operator. Operators have poor knowledge about the system on which they are working and it is advisable that a person who is prepared to be an operator has to take an exam to become entitled to work as an operator (Energy Authority of Mongolia 2010). The National Renewable Energy Centre's specialists often worked at project sites in carrying out inspections after every technical fault. The Energy Authority's experts also worked at project sites on a mission. However, the cost for every trip was very expensive due to travelling by four-wheel drive cars to soum centres remote from the capital city. Contractors did not provide sufficient technical support after installation of renewable energy systems, (Energy Authority of Mongolia, 2010).

7. Investigating design problems of installed renewable energy systems

Performance estimations for all systems and battery bank sizing calculations have been done in investigating the main design problems. The calculation methodology and principles stated in Australian Standard AS4509.9 (Stand-alone power systems – System Design Guidelines) was used. Solar radiation and ambient temperature data were obtained from NASA's website. Estimated daily load profiles and component data from real systems (12 system installations) were obtained from reports of the Energy Authority of Mongolia. Power factors used for estimating the outputs of wind turbines were assumed because wind turbines were installed at sites where no wind energy assessment has been made.

Table 11. Share of solar PV and wind turbines capacity in the total capacity

Name of soums	PV capacity as percentage of total capacity %	WT capacity as percentage of total capacity %	Type and total capacity of RE system
Tsetseg, Khovd	100%	-	Solar PV 100 kW
Mandakh, Dornogovi – old		100%	Wind only 80 kW
Mandakh. Dornogovi new	55.5%	44.4%	Solar PV 100 kW Wind – 80 kW Total 180 kW
Matad, Dornod	25.0%	75.0%	Solar PV – 30 kW Wind – 90 kW Total 120 kW
Bayantsagaan, Bayankhongor	20.0%	80%	Solar PV – 30 kW Wind – 120 kW Total 150 kW
Shinejinst, Bayankhongor	20.0%	80%	Solar PV – 30 kW Wind – 120 kW Total 150 kW
Bayan-Ondor, Bayankhongor	20.0%	80%	Solar PV – 30 kW Wind – 120 kW Total 150 kW
Tseel, Govi-Altai	20.0%	80%	Solar PV – 30 kW Wind – 120 kW Total 150 kW
Bugat, Govi-Altai	100%	-	Solar PV 160 kW
Manlai, Omnogovi	20.0%	80%	Solar PV – 30 kW Wind – 120 kW Total 150 kW

The main principle followed here was that in order to compensate for the intermittent wind in summer, approximately 20% photovoltaic generation is necessary. In the Master plan developed by JICA experts, it was advised that in order to reduce the cost of energy of hybrid systems it is preferable to have about 80% of the total capacity by wind generation and 20% of the total capacity by solar PV (JICA 2000).

Table 12: Results of performance estimation for each renewable energy systems

Name of soums	PV supply percentage of total daily load %	WT supply percentage of total daily load %	Percentage of daily deficit of energy supply %
Tsetseg, Khovd	26.5 - 50.7	-	49.3 - 73.5
Mandakh, Dornogovi – old	36.5 – 51.7	41.04 – 65.5	0.04 - 14.5
Mandakh. Dornogovi new	36.5 – 51.7	41.04 – 65.5	0.04 - 14.5
Matad, Dornod	8.1 – 14.4	39.81 - 51.18	36.8 - 53.52
Bayantsagaan, Bayankhongor	12.1 – 17.4	23.04 - 51.84	35.25 - 56.5
Shinejinst, Bayankhongor	16.8 - 21.4	26.69 - 65.99	16.34 - 57.4
Bayan-Ondor, Bayankhongor	10.8 – 14.4	19.76 - 44.38	44.5 - 69.72
Tseel, Govi-Altai	5.0 – 8.7	23.74 – 49.88	41.7 - 71.3
Bugat, Govi-Altai	37.3 – 69.9	-	30.1 - 62.7
Manlai, Omnogovi	6.4 – 14.5	16.05 – 50.88	34.8 - 77.52

The main conclusion is that sizes of installed systems were too small for supplying the daily load. In the report of the Energy Authority, it was emphasized the main reason for small size was the budget limitation. Outputs of renewable energy systems are dependent on changes of solar radiation in each month and the different number of wind turbines in operation. It was assumed that the number of wind turbines would not be constant all of the time. Consequently, there is a different percentage of supply in each month, thus only minimum and maximum percentages shown in Table 12. As capacity factors for wind turbines were assumed, their performance estimation has to be verified by checking the real generation data obtained from installation sites.

Table 13: Performance estimation result compared to actual measured output of systems

Percentage Name of soums	PV supply percentage of total daily load %	WT supply percentage of total daily load %	Percentage of daily deficit of energy supply %	Daily design load kWh	Actual daily supply (average) kWh
Tsetseg, Khovd	26.5-50.7	-	49.3-73.5	713 kWh –W 533 kWh - S	383.7
Mandakh. Dornogovi	36.5 – 51.7	22.6 – 47.14	1.16 - 40.9	772 kWh - W 503 kWh - S	368.06 W

new					
Matad, Dornod	8.1 – 14.4	39.81-51.18	34.42-52.09	700 kWh – W 599 kWh - S	201.68 W
Bayantsagaan, Bayankhongor	12.1 – 17.4	23.04-51.84	30.76-64.86	703 kWh - W 625 kWh - S	279.66 S
Shinejinst, Bayankhongor	16.8 - 21.4	26.69-65.99	12.61-56.51	607 kWh – W 491 kWh - S	176.71 Aut
Bayan-Ondor, Bayankhongor	10.8 – 14.4	19.76-44.38	41.22-64.99	820 kWh – W 730 kWh - S	317.33 Spr
Tseel, Govi-Altai	5.0 – 8.7	23.74 – 49.88	41.42-71.26	910 kWh – W 852 kWh - S	71.77
Bugat, Govi-Altai	37.3 – 69.9	-	30.1-62.7	725 kWh – W 584 kWh - S	531
Manlai, Omnogovi	6.4 – 14.5	16.05 – 50.88	34.62-77.52	897 kWh – W 566 kWh - S	222.74 W

Note: W- Winter, S- Summer, Aut – Autumn, Spr – Spring in the above table

The renewable energy systems generation data (in Table 13) obtained from the Energy Authority of Mongolia is on a weekly basis, and is not consistent. Only data for consistent period were used, and daily generation was found roughly through dividing weekly generation value by 7 days. Therefore, it is difficult to define exactly how much electricity is generated by the installed systems each day. Actual performance of the installed renewable energy systems are even below their estimated performance. Solar radiation data can be considered more reliable by using data provided by NASA, which is the result of long-term measurement. In this case, assumed capacity factors (0.10, 0.15, and 0.20) for wind turbines were high, so that outputs of wind turbines were high in performance estimation. It was highlighted in the reports of the Energy Authority of Mongolia that wind turbines were installed at sites where no wind measurements had been done. Therefore, it is possible to conclude that wind turbines have been operating with significantly lower output due to the poor wind resources at those sites.

For the two solar PV-only systems, also PV array sizing estimation was carried out.

Result of calculation for Tsetseg soum's solar PV system

- Daily load – 533 kWh – Summer , 713 kWh - Winter, Peak – 76 kW
- Required PV array size to full supply the load – 192 (min)-377 (max) kW (monthly)
- In numbers -1096 – 2152 pieces of 175 W module
- For annual average daily load profile required array size is 235.2 kW – 1344 pieces

Result of calculation for Bugat soum's solar PV system

- Daily load – 584 kWh – Summer , 725 kWh - Winter, Peak – 79 kW
- Required PV array size for fully supplying load – 213 (min)-388 (max) kW

- In numbers –1216 – 2216 pieces of 175 W module
- Annual average load 662. 16 kWh – PV size (248 kW –1416 pieces 175W)

For fully supplying the total annual load, without any capacity shortage, the PV size determined for the month with worst solar radiation and highest load (probably December or January where solar radiation is lowest and daily load is highest) would be sufficient so that all the load can be supplied without any interruption throughout a year. However, this would increase the cost of the system as the number of PV panels would increase and the battery bank size also has to be increased according to the daily load requirement.

Table 14: Battery bank sizing calculation for installed renewable energy systems

Name of soum	Battery size of current system kWh	Battery bank size for 3 days of autonomy kWh (min – max size)	Percentage of current battery size for 3 days of autonomy %
Tsetseg, Khovd	720	3840-5280	14.29 – 18.75
Mandakh, Dornogovi – old	324	3600-5520	6.26 - 9.60
Mandakh. Dornogovi new	1440	3600-5520	26.09 – 40.0
Matad, Dornod	720	4320-5040	14.29 – 16.67
Bayantsagaan, Bayankhongor	720	4320-5040	14.29 – 16.67
Shinejinst, Bayankhongor	720	3600-4560	16.67 – 20.0
Bayan-Ondor, Bayankhongor	720	5520-6000	12.0 – 13.64
Tseel, Govi-Altai	800	6240-6720	12.35 – 12.82
Bugat, Govi-Altai	1200	4320-5280	22.73 – 27.78
Manlai, Omnogovi	720	4080-6480	11.11 – 17.65

Battery bank size was determined for each month with different daily load profiles. As a result, different battery bank sizes are required in months with different daily load profiles. Minimum and maximum sizes of banks are shown in the above table. Presently, sizes of battery banks are so small that they cannot supply full load even for one day. Autonomy hours are calculated and range from 8-18 hours only.

A small sized battery bank's lifetime will be shortened due to frequent over-discharge, and being unable to be fully charged at high loads. Results show there is a lack of experience in sizing battery banks.

Finally, PV array sizing calculations for supplying 25% of the total daily load was done for solar-wind hybrid systems.

Table 15: Result of PV sizing calculation for 25% of the daily load

Percentage Name of soums	Total Daily design load kWh	25% of the total daily load	Size of PV array for supplying 25% of the total daily load	PV modules in numbers
Mandakh. Dornogovi	772 kWh - W 503 kWh - S	193.0 kWh 125.75 kWh	86.4 - 118.4 kW 45% of the total load	432-592 pieces of 200 W panels
Matad, Dornod	700 kWh – W 599 kWh - S	175.0 kWh 149.75 kWh	47.5 - 71.3 kW	288 - 432 pieces of 165 W panels
Bayantsagaan, Bayankhongor	703 kWh - W 625 kWh - S	175.75 kWh 156.25 kWh	44.8 - 63.36 kW	272 - 384 pieces of 165 W panels
Shinejinst, Bayankhongor	607 kWh – W 491 kWh - S	151.75 kWh 122.75 kWh	39.2 - 53.2 kW	224-304 pieces of 175 W panels
Bayan-Ondor, Bayankhongor	820 kWh – W 730 kWh - S	205 kWh 175.75 kWh	53 - 74 kW	320- 448 pieces of 175 W panels
Tseel, Govi-Altai	910 kWh – W 852 kWh - S	227.5 kWh 213.0 kWh	71- 122.7 kW	544-944 pieces of 130 W panels
Manlai, Omnogovi	897 kWh – W 566 kWh - S	224.25 kWh 141.5 kWh	55-121 kW	304-672 pieces of 180 W panels

The required PV array sizes were determined also for 25% of the annual average daily load by using annual average daily solar radiation values. The size of PV arrays became slightly above the average of the values shown in table 15 in terms of kW and number of PV modules.

For a detailed review of performance calculation, please see Excel file entitled pec624-Thesisd-tamk-30946612.xls (submitted online and is recorded on a DVD with other files).

8. Detailed case study of a renewable energy system

8.1 General information

8.1.1 Brief introduction about Mandakh soum

The centre of Mandakh soum in Dornogovi Aimag is located 740 km south of Ulaanbaatar city. It is about 176 km from Sainshand, the centre of Dornogovi Aimag. The soum's territory is 1412 square kilometres. It belongs to the Gobi-steppe zone of Mongolia (Energy Authority of Mongolia 2007).

The population of Mandakh soum is over 2600 or 460 households (families). Out of the total number, 1317 are herders. The number of families who live at the centre of the soum fluctuates between 100 and 150 (which is in total about 600 people) depending on the season. The main reason for this fluctuation is due to school activity. About 85-90% of the total families at the soum centre consume electricity (Energy Authority of Mongolia 2007).

The soum has three baghs (smallest administrative unit in the countryside) and the number of livestock was 64,549 at the end of 2005. About 50% of the total livestock are goats, (Energy Authority of Mongolia 2007).

At the centre of Mandakh soum, there are 17 entities and organizations such as governor's office, hospital, primary and secondary schools, dormitory for the schools, veterinary for the livestock, cultural centre, petroleum station, heating boiler, and shops running their businesses, (Energy Authority of Mongolia, 2007).

Currently, electricity is supplied to the centre of Mandakh soum by two Komatsu diesel generators with 65 kW installed capacity (installed by JICA in 2002) and one diesel generator with 100 kW (Denyo) installed capacity brought from Saihandulaan soum (connected to the grid in 2003) in 2004. Mainly due to an increase of the diesel fuel price, the diesel generator is operated only for 4-5 hours every day. The diesel plant gets diesel fuel from Sainshand (the Aimag centre) at a price of 990,000 MNT per ton (about 808 AUD). On average about 2.0-2.2 million MNT (1633-2041 AUD) is spent out of the soum's budget in every month for purchasing diesel fuel. Generated electricity is mostly consumed by households (Energy Authority of Mongolia 2007).

8.1.2 Feasibility study done by the National Renewable Energy Centre

In the “Mongolian Integrated Energy System” program (2002) approved by the Parliament, it was planned to connect the centre of Mandakh soum to the grid through a 15 kV high voltage transmission line from Saikhandulaan soum (the neighbouring soum which has already connected to the grid of Central Regional Interconnected Electricity Grid). However, in the “National Renewable Energy Program” which was approved by resolution # 32 of the Parliament issued in 2005, it was stated that electricity will be supplied to the centre of Mandakh soum by utilization of renewable energy resources (namely solar and wind resources), (Energy Authority of Mongolia 2007).

Therefore, based on the target set in the “National Renewable Energy Program”, the experts of the Renewable Energy Centre of Mongolia have carried out a detailed study of the wind energy resource at Mandakh soum’s centre in order to electrify the centre of Mandakh soum and to develop a feasibility study for this purpose. During the development of the feasibility study, the electrical demand (load) of the soum’s centre was studied in detail. From the result of the study, daily electricity demand is 772.68 kWh in winter and 503.97 kWh in summer seasons respectively. The annual electricity demand is estimated to be 250,913.6 kWh.

By considering the observed trend for future development of more small and medium sized businesses and entities, the electricity demand was increased in the calculation. The specialists of the National Renewable Energy Centre have installed a mast type of WIND EXPLORER which has a height of 20 metres at the centre of Mandakh soum and a detailed measurement was made for 3 years.
Here are some results of the measurement:

- Mean wind speed at 20 m height– 6.0 m/s
- Mean wind power 275.8 W/m^2
- Total wind energy 4,913.9 kWh/m^2
- Mean turbulence Intensity (at 10 m/s) 11.1%
- Total number of valid data 106,906
- Included number of calms 11,932
- Missing data 7,574 or 6.6%
- Best sector for wind energy is West, North West (Energy Authority 2007)

By considering the geographical location, topography and electricity demand of the soum’s centre, the BERGEY BWC XL-10R wind turbine generator was chosen for calculation of expected electricity generation. It was estimated that if this type of wind generator is installed and used then the expected possible annual electricity generation can be 39,933.3 kWh in case of fully utilizing the rated capacity. If the capacity factor is to be 28% (calculation based on

Weibull Distribution), then the expected annual electricity generation would be 19,923.6 kWh, (Energy Authority of Mongolia 2007).

In the feasibility study, three options, namely wind-diesel, PV-diesel, diesel only systems were considered and compared. An integral calculating method was used in the costing of each option. In the option for supplying electricity for the centre of Mandakh soum by using the wind energy resource, the existing diesel generator with 65 kW capacity, was considered to be part of a wind-diesel hybrid system.

From the results of the calculation, initial investment for a wind-diesel hybrid system would be 511,430.0 USD (United States Dollars) and payback period is would be 12 years. In this option, electricity generation cost was estimated to be 0.156 USD per kWh, annual average net cash flow was estimated to be 52,662.0 USD and the amount of money that will be accrued at the end of term (life-cycle) in 2024 is estimated to be 1,169,302.0 USD, (Energy Authority of Mongolia 2007).

As in the territory of Mandakh soum there are no hydro resources (flowing rivers) that no detailed study was carried out in this field.

Although, the solar energy resources have not been studied in detail, in the solar radiation atlas of Mongolia, the geographical location of Mandakh soum belongs to a zone with a solar energy resource of 1400-1600 kWh/m^2/year with the number of sunny days not less than 300 per year, (Energy Authority of Mongolia, 2007).

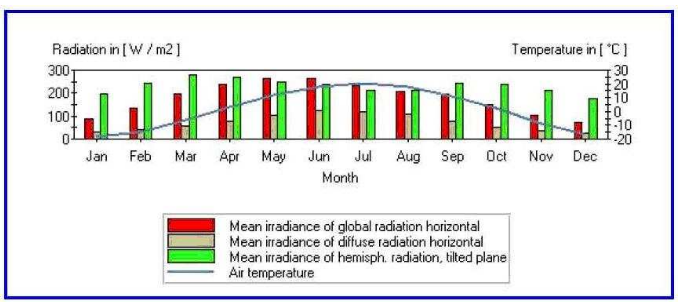


Figure 26: Solar energy resources assessed at the centre of Mandakh soum, (Energy Authority of Mongolia 2007).

Table 16. Calculated amount of solar energy in kWh/m^2/day for data in W/m^2 (Energy Authority 2007)

Months	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
kWh/m^2/day	2.16	3.24	4.68	5.88	6.6	6.72	5.88	5.28	4.68	3.84	2.40	1.82	4.43

Therefore, it is possible to utilize solar energy resources for electrification of Mandakh soum's centre. The economic calculation was carried out by using modern software and the initial investment required for a solar PV-Diesel hybrid system was estimated to be 584,423 USD. Out of this, 60 kW solar PV panels were estimated to be at a cost of 252,000.0 USD, and inverter, battery charger, and battery bank were estimated to be at a cost of 209,995.0 USD. In this option, electricity generation cost was estimated to be 0.255-0.296 USD per kWh. Seemingly, from the above result, the initial investment and electricity generation cost of a Solar PV-diesel hybrid system is relatively higher than of the wind-diesel hybrid system.

Also, another option, operating the existing diesel generator for 24 hours per day to supply the soum centre with electricity was considered in the calculation. However, the result of this calculation was that the electricity generation cost of this option was estimated to be 600 MNT per kWh (about 0.50 USD per kWh), thus it was considered economically not a viable option (consumers at the soum centre cannot afford this price). When compared with the developed options for electrification of the centre of Mandakh soum, the wind-diesel hybrid system is the least-cost option and economically viable, (Energy Authority of Mongolia 2007).

8.1.3 Generation data of renewable energy system installed at centre of Mandakh soum

Electricity production data obtained from the Energy Authority of Mongolia is not complete and for some periods there is no data available. It was explained by the Energy Authority's experts that operators sometimes do not report generation data, or data could not obtained due to technical problems related to telecommunication systems and mobile phone networks.

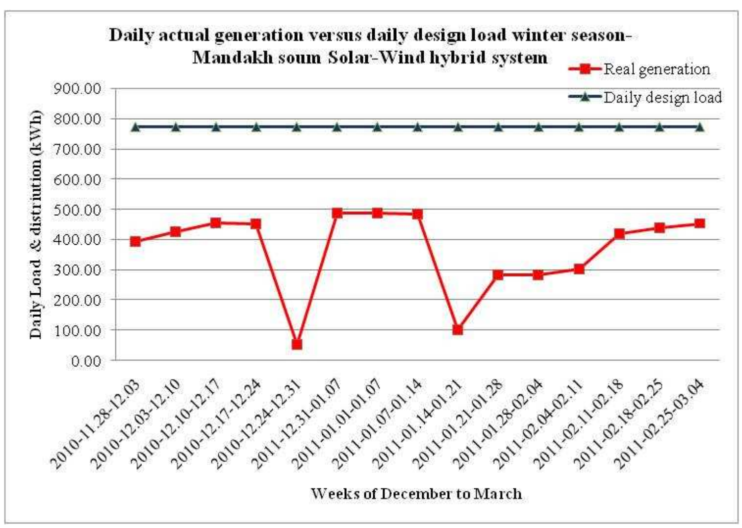


Figure 27: Roughly estimated daily generation data from weekly generation data obtained (through phone call with the operator) by the Energy Authority of Mongolia (Energy Authority 2011)

The chart in figure 28 shows the actual level of electricity generation by the Solar-Wind Hybrid system (100 kW Solar PV and 80 kW Wind) in the winter months of 2010-2011. Generation data is actually given for a week that weekly value was divided by 7 days to find out the average daily generation value. It should be noted that Korean Experts installed a 100 kW solar PV system recently at the centre of Mandakh soum, as part of the anti-desertification activity funded by the Government of the People's Republic of Korea. Daily design load is compared against daily actual generation value. The performance of the solar-wind hybrid system is that it roughly supplies about 50-60% of the daily design loads on a day with solar and wind energy resources.

8.1.4 Inputs for calculations by HOMER software

For a detailed investigation of the design of the Mandakh soum's renewable energy system, calculations based on simulation are done based on HOMER software developed by the National Renewable Energy Laboratory of the USA.

Solar radiation, ambient temperature, and wind speed data were obtained from NASA's website by entering the latitude and longitude of Mandakh soum's centre which was obtained by using the Google-Earth program. It was not possible to obtain measured wind data from the National Renewable Energy Centre of Mongolia. Load data, especially the hourly load profile, was obtained from the Energy Authority of Mongolia. Component data from the real system was used and detailed cost data of the 80 kW Wind system was obtained from the Renewable Energy Department of the Energy Authority of Mongolia. Cost values expressed in Mongolian currency MNT were converted into United States Dollars by using an official exchange rate for the year 2008 announced by MONGOLBANK (the central bank of Mongolia): 1USD=1250MNT.

Mandakh soum's data – Dornogovi Aimag, Mongolia

Latitude 44.24^{o}N / Longitude 108.15^{o}E was chosen.

Parameters for Sizing and Pointing of Solar Panels and for Solar Thermal Applications:

Table 17: Solar radiation data of Mandakh soum (NASA 2011)

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m^2/day)													
Lat 44.24^{o}N Lon 108.15^{o}E	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	2.22	3.31	4.69	5.88	6.58	6.70	6.17	5.47	4.74	3.47	2.38	1.85	4.45

Parameters for Tilted Solar Panels:

Table 18: Solar radiation on tilted plane of array (altitude angle+15 degrees) Mandakh soum

Monthly Averaged Radiation Incident On An Equator-Pointed Tilted Surface ($kWh/m^2/day$)													
Lat 44.24°N Lon 108.15°E	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Tilt 59	5.35	5.86	6.26	5.80	5.29	4.95	4.75	4.88	5.46	5.54	5.13	4.31	5.29

Table 19: Ambient temperature at centre of Mandakh soum (NASA 2011)

Monthly Averaged Air Temperature At 10 m Above The Surface Of The Earth (°C)													
Lat 44.24 Lon 108.15	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	-23.2	-18.8	-6.78	6.19	14.7	20.6	22.6	20.0	13.1	3.43	-8.36	-19.1	2.14

Table 20: Wind speed at 10 m height at centre of Mandakh soum (NASA 2011)

Monthly Averaged Wind Speed At 10 m Above The Surface Of The Earth For Terrain Similar To Airports (m/s)													
Lat 44.24°N Lon 108.15°E	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	4.76	4.68	4.99	5.57	5.17	4.92	4.48	4.32	4.65	4.86	5.23	4.87	4.87

Three different daily load profiles were used. Daily load profiles were estimated by specialists of the National Renewable Energy Agency during the pre-feasibility study.

Table 21: Estimated daily load profiles of Mandakh soum's centre

Time of Day	Summer kW	Winter kW	Autumn/Spring kW
0	4.72	8.67	5.27
1	1.12	2.12	1.72
2	1.12	2.12	1.72
3	1.12	2.12	1.72
4	1.12	2.12	1.72
5	8.00	10.48	8.48
6	13.79	19.64	15.64
7	22.85	22.83	22.81
8	14.53	31.91	17.64

9	17.43	24.99	18.99
10	14.64	23.53	16.53
11	18.91	26.32	18.52
12	28.50	36.69	29.69
13	24.72	32.92	25.92
14	14.97	24.66	15.66
15	18.64	38.29	28.29
16	26.27	35.12	27.21
17	42.10	63.26	54.24
18	52.92	71.57	62.57
19	56.07	76.00	68
20	55.18	72.24	64.24
21	43.69	65.85	58.85
22	19.49	53.51	46.51
23	8.86	32.53	26.26
Daily	503.97 kWh	772.68 kWh	638.32 kWh
Months with Profile	Jun, Jul, Aug	Nov, Dec, Jan, Feb, Mar	Apr, May, Sep, Oct,

A detailed calculation of the load can be seen from a file entitled pec624-Thesisb-tamk-30946612.xls.

Component data from real system - old system 80 kW wind only

Table 22: Information about components of 80 kW wind only system installed initially

Wind turbine	Beijing Bergey Wind power B 10XLR type 10 kW - 8 pieces
Inverter	Champion-310 type 80 kW
Rectifier	3x380, 60kW, GDF-60KW, China
Battery	GFM-450 type 2V, 450 Ah - 360 pieces (324 kWh)
Charge regulator	Beijing Bergey Wind power

Components of newly added system - 100 kW Solar PV system

Table 23: Component data of solar PV system installed by Korean experts in 2010

Solar PV	SM-200PDO manufactured in Korea (500 pieces)
Inverter	120 kW manufactured in Korea
Battery	GFM-1000 type 2V, 1000 Ah – 720 pieces (1440 kWh)

Data of existing diesel generator

Table 24: Data of existing diesel generator at centre of Mandakh soum

Denyo (Japan)	100 kW (year of manufacture 2000) three phases
Fuel consumption	33.0 l/hr at rated capacity

Detailed cost data of the wind only 80 kW system installed at centre of Mandakh soum was obtained from the Energy Authority of Mongolia. The price was expressed in Mongolian currency tugrug – MNT which was converted into USD by using Mongolbank's official exchange rate. Detailed cost data can be seen from Appendix V of this paper. Bergey's B 10XLR type wind turbine's load curve in the HOMER database was used. The battery specification was obtained from the manufacturer's website. Inverter and rectifier efficiencies were assumed. Solar PV cost was assumed as 12$/Wp and the new battery bank cost was assumed as 220US$ per battery. The diesel generator's price was obtained from the Ministry of Mineral Resources and Energy. The price in year 2000 was 25.0 million MNT and assumed a price increase of 40% in 2008 so that final diesel price was 35.0 million MNT in 2008. Using the exchange rate of 2008 (1USD=1250) the price of 65kW diesel generator was assumed as 28000USD in 2008. Diesel fuel price was 0.8US$/l in 2008 in Mongolia, (NSO 2008). For the sensitivity analysis, different prices of diesel fuel 1.0, 1.2, 1.4, 1.6 US$/l were used.

Calculations were done for four options.

A. 80 kW wind only system with a battery bank of 324 kWh and an inverter with 80 kW capacity
B. 100 kW diesel only
C. 100 kW Solar PV +80 kW wind with a battery bank of 1440 kWh and an inverter with 120 kW capacity)
D. 65 kW Diesel+100 kW PV+ 80 kW Wind , 1440 kWh battery bank, 120 kW inverter

8.2 Results of the simulation, optimization and sensitivity analysis done with the HOMER Program

8.2.1 80 kW Wind, 324 kWh Battery bank, 80 kW inverter system

HOMER gave a warning message that the system is not feasible due to a capacity shortage constraint and recommended to add more wind turbines, add more batteries and increase capacity of the converter.

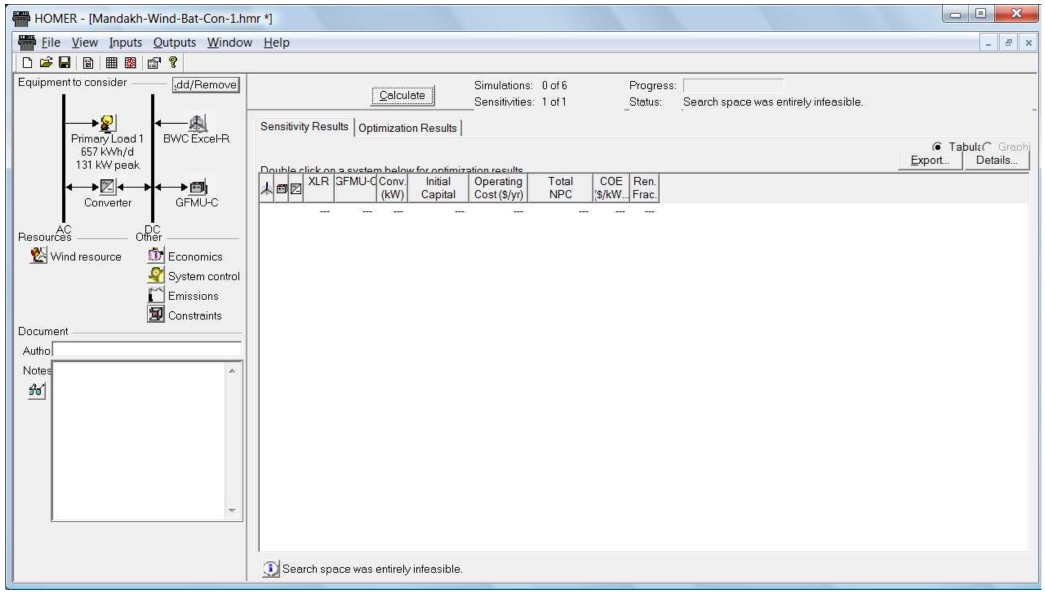


Figure 28: dump of the HOMER's result for existing 80 kW wind only system

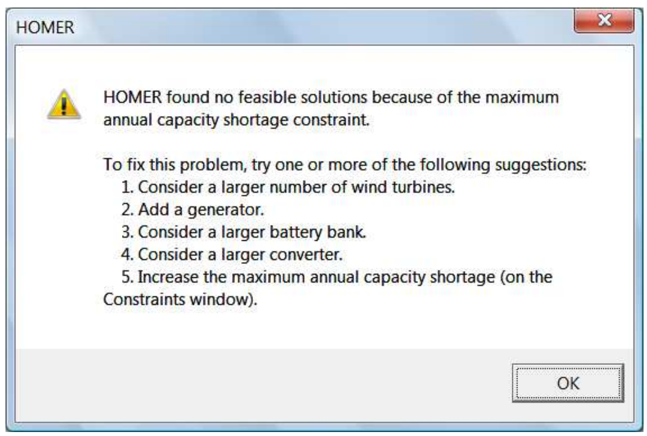


Figure 29: HOMER's suggestions for the existing 80 kW wind only system installed at Mandakh soum

The system only can be feasible if the capacity shortage is 0.79 and in this case it can supply about 40% of the annual load. However, HOMER suggested to increase capacity of the battery bank.

Table 25: Result of simulated wind only 80 kW system with capacity shortage of 0.79

Initial capital cost $	Operating cost $/yr	Total NPC $	COE $/kWh	Renewable fraction	Capacity shortage	Unmet electric load %
383,397	11,489	506,034	0.489	1.00	0.79	59.6

Although, the unit size of a wind turbine is 10 kW actually in the technical specification of the Bergey B 10XLR wind turbine, it states that its capacity is only 7.5 kW in case of DC mode for a battery charging. That means total installed capacity of wind turbines is 60 kW.

HOMER warns that the capacity of the battery bank is small and needs to be increased. Wind only 100% supply of the daily load is difficult to achieve and expensive. Two different calculations made to check the option of having enough capacity by wind only system.

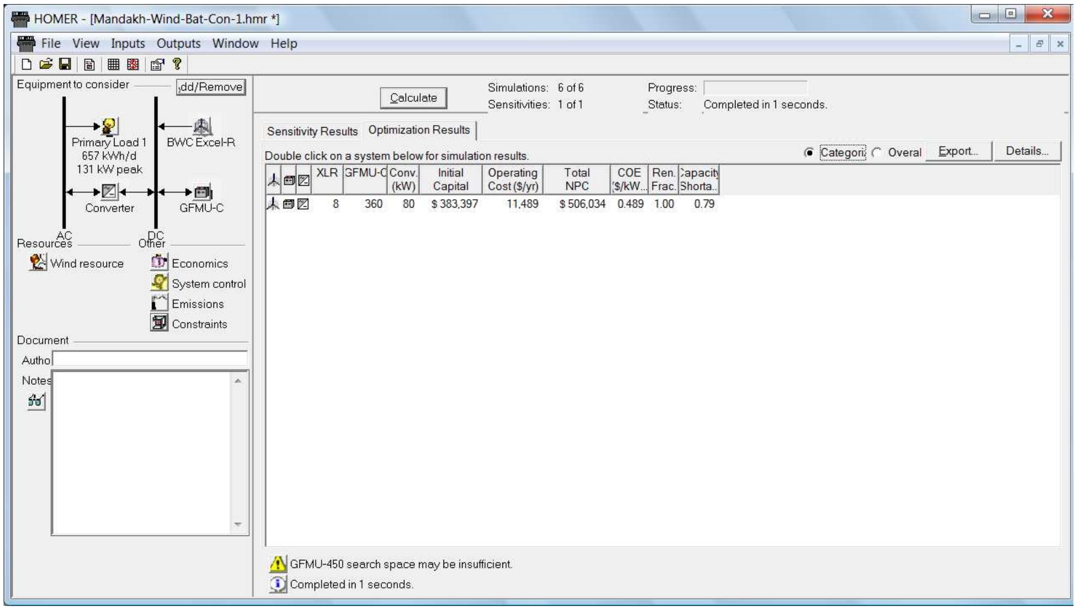


Figure 30: Results of HOMER when it considered the existing wind only system feasible. (Simulation can be seen in a file entitled pec624-Thesise-tamk-30946612.hmr)

In the first option, increased numbers of wind turbines with small capacity (BERGEY 10XLR), adding more batteries (with same characteristics), increasing capacity of inverter, increasing cost for cable depending on the number of wind turbines.

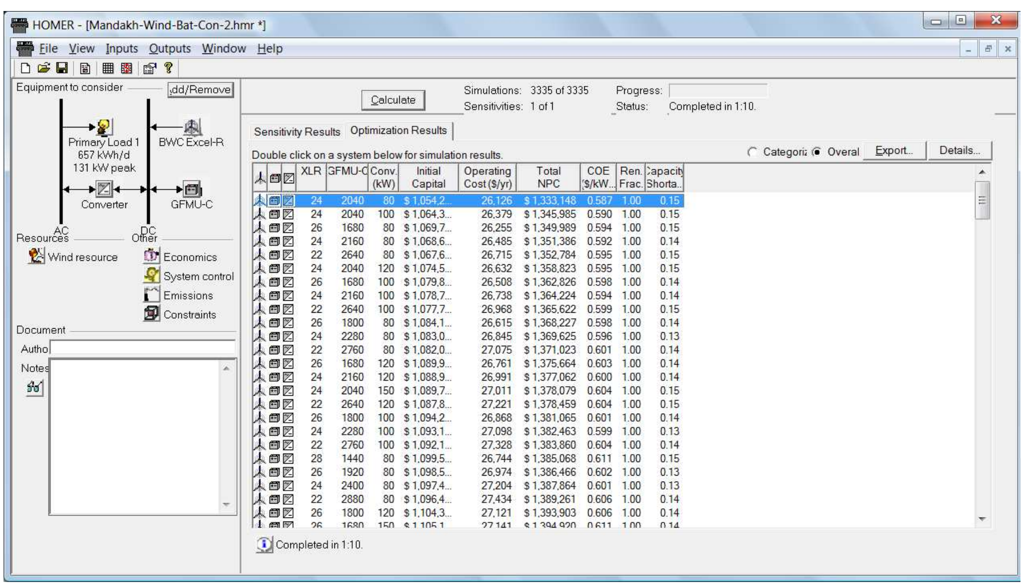


Figure 31: The optimal configuration out of many possible options of wind only system

(Simulation can be seen in a file entitled pec624-Thesisf-tamk-30946612.hmr)

The result is that it is possible to achieve capacity shortage percentage of 0.15 if the number of total wind turbines is 24, size of battery bank is 1836 kWh, and size of inverter is 80 kW.

Table 26: Results of the optimal configuration of the wind only system

Initial capital cost $	Operating cost $/yr	Total NPC $	COE $/kWh	Renewable fraction	Capacity shortage	Unmet electric load %
1,054,200	26,126	1,333,148	0.587	1.00	0.15	11.3

However, this option can be unrealistic in that for installing a larger number of wind turbines, the land area required should be increased greatly, and the number of batteries has to be increased which requires more initial capital cost. Capacity shortage can be achieved up to 0.08, but it will increase the initial capital cost and net present cost thus will be listed in the last ranks of the optimization list.

The second option evaluated the situation, if instead of having many small sized-wind turbines, instead there was a smaller number of larger wind turbines to supply the total load. However, the result of thus simulation was worse than having many small-sized wind turbines.

It is possible to achieve capacity shortage of 0.34 if nine 20 kW wind turbines were used with a battery bank of 1296 kWh, and an inverter size of 120 kW. Increasing the number of wind turbines further will not give better outcomes, but it will tend to have the same level of cost compared to the option of using many smaller wind turbines.

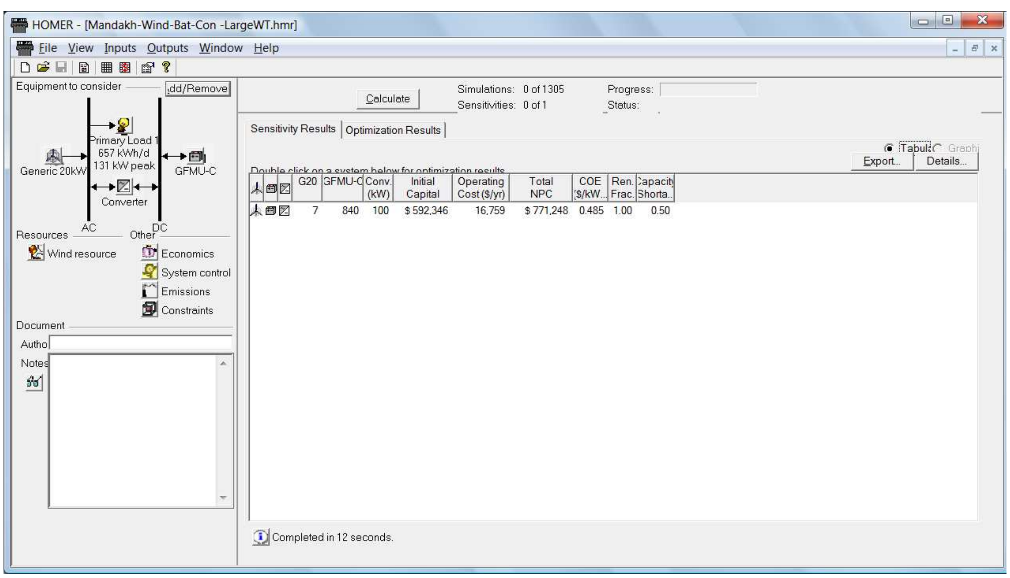


Figure 32: Result of simulation in case of using larger wind turbines

(Simulation can be seen in a file entitled pec624-Thesisg-tamk-30946612.hmr)

Table 27: Result of simulation with larger wind turbines

Initial capital cost $	Operating cost $/yr	Total NPC $	COE $/kWh	Renewable fraction	Capacity shortage	Unmet electric load %
781,866	21,232	1,008,815	0.530	1.00	0.34	25.6

The main reason for not achieving a lower capacity shortage is that a wind turbine with more capacity (20 kW) works at its rated power when the wind speed is around 12-14 m/s. However, at the project site the mean wind speed is about 5-6 m/s. Thus a wind turbine with a larger capacity will utilize only a small portion of its rated capacity at lower wind speed. On the contrary, smaller wind turbines (7.5-10 kW) work their rated capacity at a wind speed range of 8-10 m/s. Thus, small wind turbines can utilize their rated capacity better at a lower wind speed range.

8.2.2 100 kW diesel only option

The existing diesel generator was installed in year 2000 and has been operated for about 11 years up to now. Although it was operated for 4-5 hours in each day regular maintenance and major overhaul were not carried out up to now. Therefore, a price of new diesel generator was considered in the calculation. The advantage of this option is that there will not be any capacity shortage. However, it will provide excess electricity equal to about 39.4% of the annual total load. It is mainly due to the fact that, the diesel generator's capability to operate at lower load is limited to 40% of its rated capacity. Thus, excess energy of the diesel generator would cause a serious problem related to glazing of cylinders if it is operated below 40% of the rated capacity and it would deteriorate quickly and require more maintenance.

Table 28: Result of simulation of 100 kW diesel only system

Initial capital cost $	Operating cost $/yr	Total NPC $	COE $/kWh	Renewable fraction	Capacity shortage	Excess electricity %
122,886	161,513	1,847,001	0.723	0.00	0.00	39.4

Although, this option has low initial capital cost, its operating cost and ongoing maintenance cost is high. Also the cost of the electricity generated is high. In this option, the price of diesel fuel was considered to be 0.8 US$/L which was the price in 2008. If the price of diesel fuel increases then the cost of energy will be increased further. Currently, the affordability for people living at the soum centre is low and they pay around 0.08US$/kWh, (ERA, 2011). Therefore, the price of 0.723 $/kWh is far beyond their affordability. Mongolia imports all kinds of petroleum products from the Russian Federation, and the price of petroleum products increases 3 times a year on average. (NSO 2008)

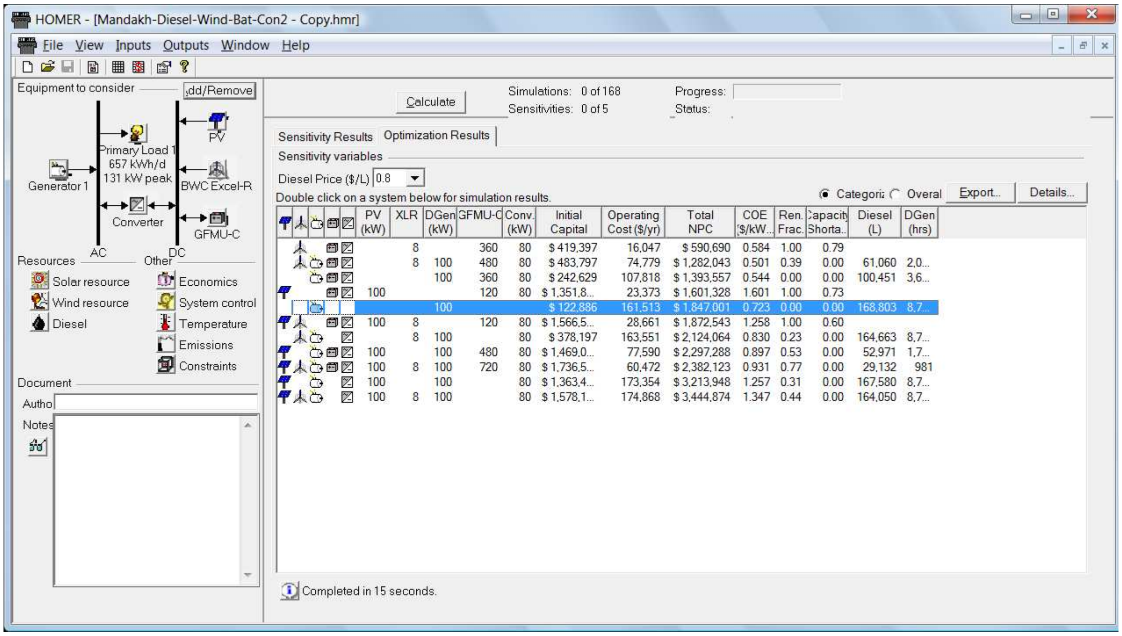


Figure 33: Result of simulation 100 kW diesel only system (Simulation can be seen in a file entitled pec624-Thesisi-tamk-30946612.hmr)

Nowadays, soum centres do not have required workshops, techniques, and qualified people for carrying out ongoing maintenance such as top overhaul and major overhaul of diesel generators. In the past, during the communist period, there was a separate organization called "Diesel Generators Repair and Maintenance Authority" which was responsible for organizing regular inspection, maintenance, and transporting diesel generators to the capital city for major overhaul. However, such an organization no longer exists and there is no such service available in rural soum centres with diesel generators. Therefore, it has become difficult to operate diesel generators in rural areas of Mongolia now.

8.2.3 100 kW Solar PV + 80 kW Wind with 1440 kWh battery bank and inverter size of 120 kW

A 100 kW solar PV system was installed at the centre of Mandakh soum two years after the installation of the wind only system as part of the anti-desertification project financed by the Government of the People's Republic of Korea in 2010. The system was installed by experts of Daesung Group (Daegu City Gas) of Korea and its cost was about 2.9 million Korean won, (Energy Authority of Mongolia. 2011). The battery bank of the wind only system deteriorated due to regular over-discharge and insufficient charging so that the old battery bank was discarded upon installation of the new system. A new battery bank with a capacity of 1440 kWh and an inverter with 120 kW capacity were installed. The system was interconnected to the 80 kW wind-only system, and the system started to work as a Solar-Wind hybrid system in September, 2010.

The results of simulation indicate that a solar-wind hybrid system can supply about 88% of the annual load, but it is expensive and its output depends on the availability of solar and wind resources (weather conditions).

Table 29. Results of simulation of PV-Wind hybrid system

Initial capital cost $	Operating cost $/yr	Total NPC $	COE $/kWh	Renewable fraction	Capacity shortage	Unmet electric load %
1,612,400	27,514	1,906,178	0.830	1.00	0.14	10.3

The result of this simulation contradicts the advice given by the experts of the Energy Authority that the reliability of power supply can be ensured fully by installing additional solar PV generators. However, even though 100 kW solar PV capacity was added on the existing system, it is still unable to supply all of the load throughout the year without some additional electricity. It is clear that the costs are high to provide enough generation capacity from renewable-only generators.

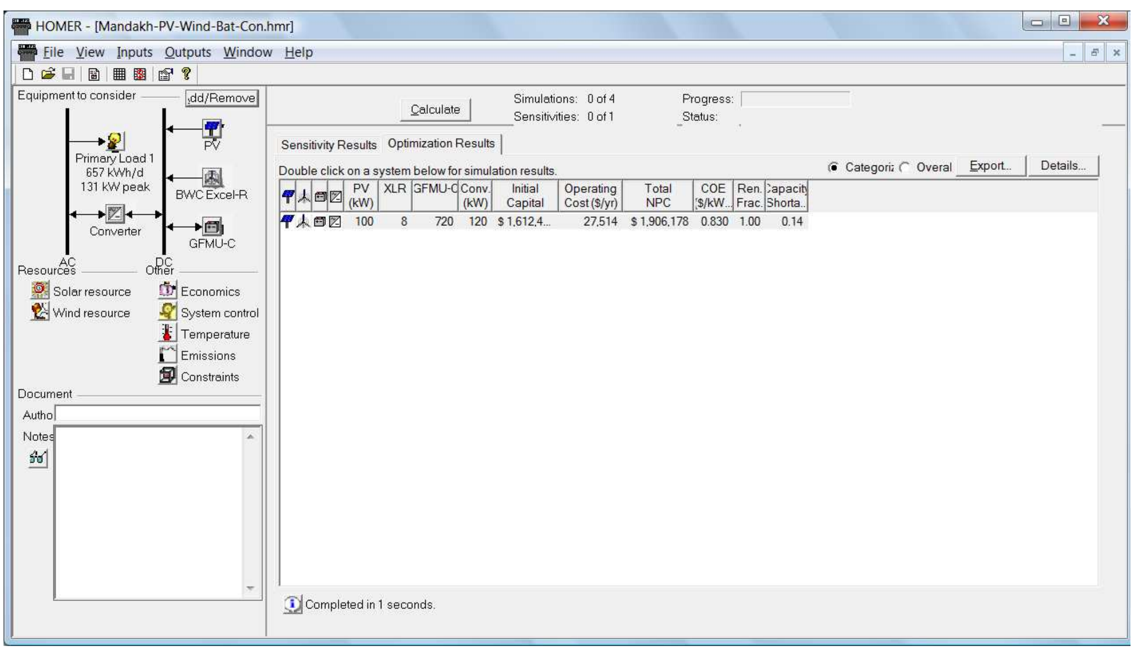


Figure 34: Results of simulation of 100 kW PV- 80 kW Wind Hybrid System

(Simulation can be seen in a file entitled pec624-Thesish-tamk-30946612.hmr)

8.2.4 65 kW or 100kW Diesel+100 kW PV+ 80 kW Wind, 1440 kWh battery bank, 120 kW inverter

The last calculation was done with an aim of investigating the operation and life cycle cost of a diesel and renewable generator (PV, Wind) hybrid system. Another, purpose of this calculation is to identify the best option to see which configuration fits best to the load situation at Mandakh soum's centre. A sensitivity analysis was done by changing the price of diesel fuel by various percentage increases.

Table 30. Result of optimal hybrid system - diesel (65 kW) + PV (100 kW) + Wind (80 kW) system with battery bank 216 kWh, and 80 kW inverter. However, this configuration ranked at 4th place in the list of optimization from various configurations of the system.

Initial capital cost $	Operating cost $/yr	Total NPC $	COE $/kWh	Renewable fraction	Capacity shortage	Excess electricity %
1,624,200	65,706	2,325,646	0.910	0.72	0.00	33.1

In this configuration, there will not be any capacity shortage but instead, some excess electricity. Its operating cost is much cheaper than the diesel only system but its total net present cost is much higher than for the diesel only system. The cost of energy also higher, and it is not affordable for consumers. A sophisticated main control system is required to be installed in this case for regulating the hybrid system's operation (synchronization, start of diesel generator etc).

The diesel-wind system is considered as the best by the HOMER program in terms of capacity shortage, total net present cost, and cost of energy.

Table 31: Result of the best option from list of configurations of the power supply system (80 kW wind -65 kw diesel- 360 cells of battery)

Initial capital cost $	Operating cost $/yr	Total NPC $	COE $/kWh	Renewable fraction	Capacity shortage	Excess electricity %
450,647	71,042	1,209,004	0.473	0.40	0.07	5.76

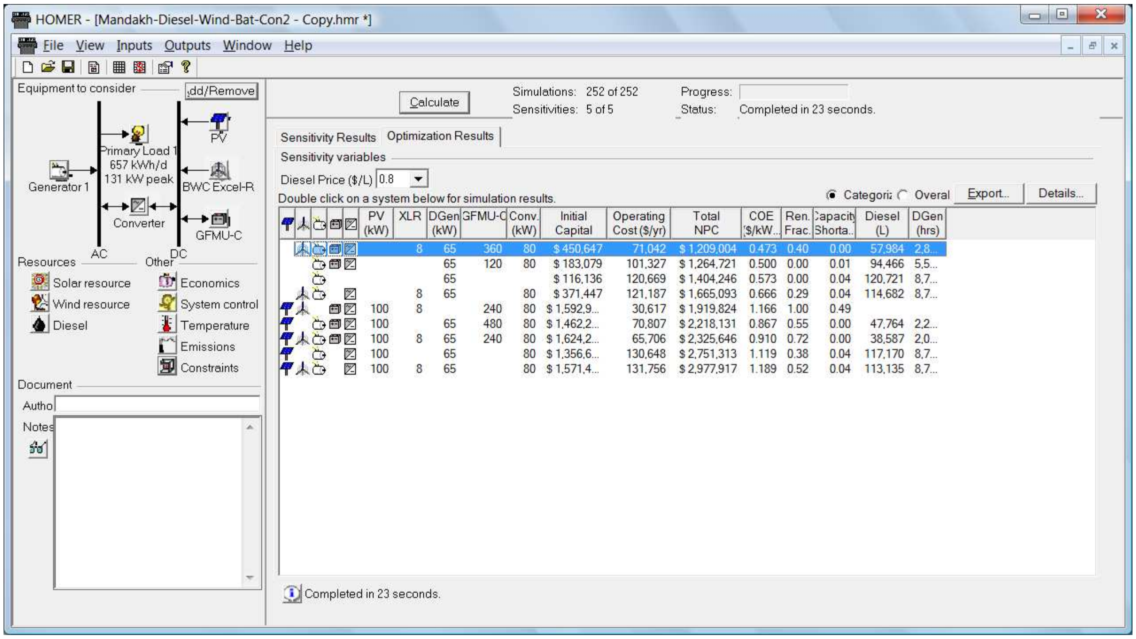


Figure 35: Result of simulation and optimization from various configurations

(Simulation can be seen in a file entitled pec624-Thesisi-tamk-30946612.hmr)

Even though the diesel price is 1.6 $/L (which was increased by 100% from the initial price of 0.8 $/L) HOMER still determines the diesel-wind system as the optimal configuration. The Solar-Wind only hybrid can become cheaper than the diesel only option but still have some capacity shortage. For a level of electricity supply without the capacity shortage (or with minimum value) the total net present cost of the Solar-Wind Hybrid system (100 kW PV+80kW wind+240 cells of batteries) still be more than the total net present cost of a diesel only (65 kW) system.

Table 32: Example of Solar-Wind Hybrid system with increased capacity to reduce the capacity shortage (when Solar PV is 150 kW, 12 units of Bergey XLR 10 wind turbines, inverter is 120 kW, and battery bank size is 216 kWh).

Initial capital cost $	Operating cost $/yr	Total NPC $	COE $/kWh	Renewable fraction	Capacity shortage	Unmet electricity %
2,320,600	39,455	2,742,731	1.491	1.00	0.40	28.1

Even when capacity of the solar PV, number of wind turbines, and size of the inverters are increased (to size stated in header of table 32) there is still a capacity shortage of 40% with unmet electricity of 28.1 % of the total annual load. However, in this case, the initial capital cost, total net present cost and cost of energy became more expensive than the Diesel-PV-Wind-Battery-Inverter system.

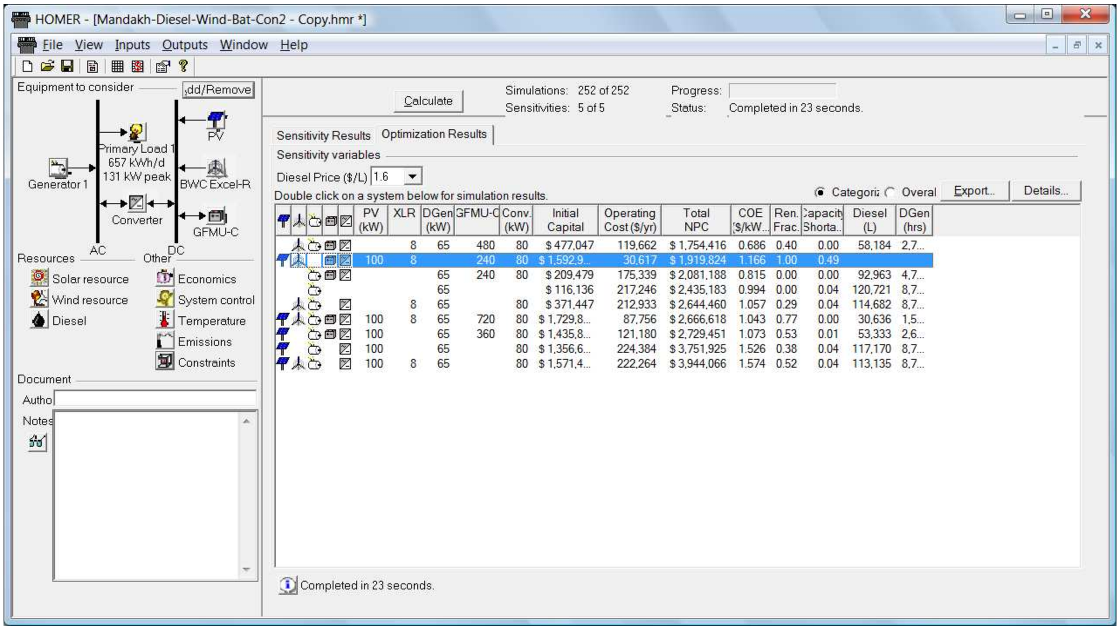


Figure 36: Scenario when diesel fuel price is 1.6 $/litre

(Simulation can be seen in a file entitled pec624-Thesisi-tamk-30946612.hmr)

8.3 Conclusion of calculations done by using the HOMER software

Due to lack of measured wind data, the wind data obtained from NASA's website was used. Wind speed and direction should be measured in advance and a detailed assessment should be done before installing wind turbines. Such measures would enable the Government to avoid the installation of wind turbines at sites with low wind resource or with almost no wind resources. Also, it will help to increase the output of wind turbines if they are installed at good wind resource sites.

Based on the results of the above calculations, it is possible to conclude that achieving 100% of power supply (without any capacity shortage) by a renewable-only system is difficult. The renewable energy system has to work between two extremes of minimum and maximum loads. To supply the peak load during the low renewable energy resource period the system capacity has to be large. Thus, it will increase the initial capital cost. It is clearly visible from the above result that reaching a level without or with only minor capacity shortage by a renewable-only generator is difficult to reach in terms of cost of the system. A solar-wind only hybrid system is possible technically, but economically it would be more expensive than diesel only and diesel-wind-PV systems.

In the Mongolian case, daily load at soum centres ranges between 491 – 910 kWh. Much larger renewable-only systems are required to supply the demand without a capacity shortage.

Thus, renewable-only generators can be more suitable for lower daily load situations. According to the calculation, the size of the initially installed wind-only system at the centre of Mandakh soum was actually very small and thus unable to supply the load.

The performance of solar-wind hybrid systems depends on weather conditions seasonally. In the winter season, when the solar and wind energy resources are at a low level the output of currently installed systems decreases significantly. Therefore, a backup generator is required at least during the low resource (solar radiation and wind speed) and high load period (the winter season) in order to increase reliability of power supply and prevent the battery bank from possible over-discharge. It is advisable that existing diesel generators should be interconnected to a newly installed renewable energy system. However, required devices and a control system have to be installed for this purpose (a synchronizer and a controller etc).

9. Barriers to rural electrification by renewable energy

Limited financing – The installed 12 renewable energy systems capacity is not enough, thus they experience deficiency in power supply even during the high resource (solar and wind) period. Due to budget constraint, all components were undersized leading to problems of overloading of the system. Another consequence of budget constraint is that devices with low or cheap prices were purchased (supplied) but their quality was not good.

Selection of potential contractors - Selection of contractors with no experience in installation of energy systems through the direct contract method had a negative impact related to the quality of installation work, choice of devices, lack of experience in organizing proper training and supplying required operation and maintenance manuals. In fact, the Government's sudden decision to implement the projects directly led to the selection of contractors with no experience.

Lack of preparatory work – Wind energy resource assessment has not been done at 9 places where wind-solar hybrid and wind-only systems have been installed. It is difficult to estimate the expected production by wind turbine generators unless a wind speed distribution plot is available. In fact, the sudden decision of the Government was the main reason for lack of preparation because projects financed out of the state budget have to be implemented within one year (at maximum two years). The implementation of the projects was not done in accordance with the preliminary set for development. Only the daily load in each hour of the day was estimated roughly during the pre-feasibility study.

Lack of professional staff in design, installation, and maintenance – System configurations were not ideal for their smooth functioning. Much time was wasted in doing the detailed design. Owing to lack of experienced experts, detailed design papers were delayed at State Supervision Agency for review by state experts. Sizes of the systems were not sufficient for supplying daily loads. Sizes of battery banks were too small in terms of providing energy during the low resource period. Common problems occurred after installation due to incorrect installation of wind turbines, battery banks and solar PV arrays. Maintenance was at a low level for the 12 installed renewable energy systems. Repair of broken components and maintenance of components always required input from experts and specialists from the capital city (not available even at the Aimag centre). In some cases, experts from the capital city were not able to fix the problem or to carry out the maintenance. Therefore, in several cases engineers from manufacturers came to the installation site to remedy the problems and execution of proper maintenance.

Lack of experience in installation of large RE systems - Renewable energy systems (solar PV only, wind-only, solar-wind hybrid) which had been installed in rural areas of Mongolia were small-sized systems (0.5 – 25 kW). Only once a Furlander-type wind turbine with a 100 kW capacity was installed at Erdenetsagaan soum of Sukhbaatar Aimag. However, the project was implemented by energy sector experts, including experts with sufficient knowledge and experience who used to work at Hamburg Technical University of Germany (specialist from the National Renewable Energy Centre did not participate in this project). Therefore, specialists from the National Renewable Energy Agency and Contractors did not have any experience in installation and operation of large scale renewable energy systems at rural soum centres.

Poor training for local operators – In fact, some faults occurred due to the operator's wrong actions. Training for operators was not organized at a satisfactory level. Even Contractors themselves did not have any experience of operation and maintenance of renewable energy systems. Contractors have difficulty in translating manuals from English to Mongolian due to lack of experts who have both knowledge of engineering and language. It was difficult to find a proper person (with sufficient base education and working experience on electrical systems) from rural soum centres. In many cases, former diesel operators were chosen to take part in the training and to become the operator.

Lack of management - Currently, the power supply business at a soum centre is managed by the office of the soum's governor. The power supply department works under the management of the soum's governor. It usually consists of 2 or 3 people in charge of operation and a daily minor service of the power system, and a sales inspector. The power supply organization should be completely separated from the soum governor's office. Almost in all 12 soum centres, the distribution networks were rehabilitated as part of the World Bank's project in 2009-2010. New meters have been installed for every user. Shift to a meter-rated tariff system (before all soums had fixed tariffs) would require additional man-power for meter reading and collecting sales revenue. A part-time third party commission called the "Regulatory Board of Aimag" reviews and approves the tariff of energy licensees (generators and distributors) in the territory of the Aimag according to the Energy Law of Mongolia. However, a proposal for tariff increase has to be made and submitted by an electrical generation licensee. In fact, the soum's administration and people working at a power supply unit do not have the knowledge to develop a proposal for a tariff increase. Even at some soums, their governors had fired initially trained operators and appointed other people who did not have any knowledge about the renewable energy system as operators. Management should be carried out at a professional level otherwise, it is not sustainable in the long term. It is one of the important barriers to renewable energy utilization in rural areas. When poor management prevails, conditions of installed systems get worse quickly and non-professional managers can take inappropriate decisions.

Remoteness of areas – Remotely located soum centres are difficult to access. These soum centres sometimes experience lack of communication during the stormy periods when telecommunication lines get disconnected due to a damage. Travel cost to remote soum centres is high. Experts usually travel by jeep for 1 to 3 days (680 -1500 km) to reach the installation site. In very remote areas it is difficult to find qualified people who can work as an operator.

Ownership issue is unclear – The renewable energy systems were established by funds provided out of the state budget. However, in fact, they have been operated and managed by soum administrations which have no experience, no qualified specialists, and no maintenance facilities. Currently, the assets are only considered as state property, but there is no separate organization that owns the installed renewable energy systems. Therefore, the ownership issue must be resolved clearly in order to determine the status of the property, and obligation of the organization, which would own the systems. The Government needs to promote private sector participation in this case so that the plant can be given to a private professional entity under a management contract or concession agreement for a long period. Ownership will improve the management of the installed systems.

Deterioration of local distribution networks and high distribution loss – Low voltage distribution overhead lines were built around 1960s and had been essentially worn out. The technical condition of local low voltage networks was bad. The distribution systems were owned by communes which were abolished after the privatization in the 1990s. The World Bank and JICA reports highlight the deteriorated condition of the distribution networks especially the high level of loss of about 20-50% of the total distributed energy. (JICA 2000). Distribution networks of 12 soums were rehabilitated in 2009-2010 as part of the project "Electrification of Rural Areas by Renewable Energy" which was funded by the World Bank. The Government of Mongolia had intended to finance this work, but due to a budget deficit it could not finance it. For the remaining 10 soum centres, if the Government intends to install renewable energy systems then at first it is necessary to restore the deteriorated low voltage distribution networks. Otherwise, significant losses would burden the renewable energy system and the size of the system should be high enough to supply the full demand.

Low tariff – Although, it is stated in the Renewable Energy Law of Mongolia that the difference between a regular retail tariff and a tariff for electricity supplied by stand-alone renewable energy generators will be provided from the renewable fund of the special fund of the Government, nothing has been provided yet. In reality, enforcement of the relevant clauses of the Renewable Energy Law of Mongolia is not taking place. As rural people's affordability is low, then the difference should be provided by the central government as stated in the Renewable Energy Law of Mongolia. It is necessary for earning sufficient funds for covering regular maintenance and replacement costs in due time. In case no fund is provided by the Government in the future, then it will be necessary to increase retail tariffs to cover all associated costs.

Fixed tariff – Currently, all soum centres use a fixed tariff, which creates no incentive for users to save energy. In the future, at least the energy tariff should be set and be used for improved supply management and enforcement that consumers have to pay for the amount of electricity consumed. Thus, consumers would follow the energy conserving way. However, one of the reasons for using a fixed tariff is because of the absence of meters installed at consumers' premises. Recently, as part of the World Bank project, electricity meters have been installed at consumers so that it became possible to apply the energy tariff. However, a meter reader is required for billing consumers.

Significant difference between Summer and Winter season load at soum centre – Mainly due to changes in the number of people staying at a soum centre, and the traditional way of living, for instance everybody having a vacation in the summer time, school and kindergarten close during the summer season. The generator size has to be large enough to cope with a high load in the winter season where availability of solar radiation and wind resource are low. The effect of this is to increase the initial capital cost of the renewable energy system.

Unenlightened consumers and Need for the Demand management – For consumers who historically had very cheap electricity supply for 24 hours during the communist period, a carefully planned public education program is required for enlightening consumers to a completely different power supply situation. It is necessary to organize general training on the main operating principles of renewable energy generators. Especially this should include training about their dependence on weather condition and the need to adjust energy consumption during the low resource days. At all soums, energy efficiency and measures are desirable before installation of renewable energy systems in order to decrease the load. Consumers should be aware of how a renewable energy system functions, and the necessity of scheduling their energy consumption according to the generation capacity of the systems. The

ADB report mentioned that consumers without such knowledge did not manage their consumption, and renewable energy systems were shut down due to overloading conditions. Also battery banks were over-discharged and damaged due to exceeding the maximum load within a short period (ADB 2007).

10. Drivers for rural electrification by renewable energy

National Renewable Energy Program - This was developed by the Government of Mongolia and approved by the Parliament of Mongolia in 2005. It is the main policy paper of the Government that aims to promote the development of renewable energy in Mongolia. The Government's target to increase the share of renewable energy in total electricity production is stated in this paper and various steps towards this achievement have been put into the program. The electrification of rural areas by renewable energy was one of the high priority targets set by the Government of Mongolia.

Renewable Energy Law – The Energy Law of Mongolia, which came into force in 2001, does not have any clauses regarding regulation of renewable energy businesses and energy production by using renewable energy generators. Therefore, a new separate law, designed to regulate various aspects of renewable energy business, was developed and came into force in 2007. The Renewable Energy Law of Mongolia guarantees feed-in tariffs for renewable energy generators. The law also states that the power purchase agreement has to be made between the Generator (investor) and the Transmission Company in case of utility scale renewable energy plants. Tariffs for stand-alone renewable energy systems in rural areas have to be subsidized from the renewable energy fund according to the Law of the Government's Special Fund.

Renewable energy resources – Mongolia has abundant solar, wind, and hydro resources which can be utilized by large and small scale renewable energy systems in generating electricity. Renewable energy resources of Mongolia have been assessed since the 1980's and recently many assessment studies have been done. As a result, new maps and atlases have been released. Utilization of small scale renewable energy systems has proven the abundance of renewable energy resources.

Remote area with no grid access – Such inaccessible areas have difficulty in transporting diesel fuel during the snowy winter season and also in the rainy summer period. Therefore, only renewable energy technology became a suitable option or preferred choice as a power supply solution. In this case, costs for operation and maintenance of diesel generators, and constructing high voltage transmission lines with substations would actually be more expensive than installing and operating renewable energy systems.

Need to improve social service for people – The Government's main goal is to reduce the difference in living standards between people living in rural and urban areas in order to decrease the migration towards the cities. Reliable and continuous power supply would improve the operation of schools, kindergartens, and hospitals etc. Because of this requirement, the Government is willing to finance and implement renewable energy projects in rural areas.

Diesel fuel price increase - As Mongolia imports all petroleum products from Russia, and Russian suppliers continue to increase the price of petroleum products quarter by quarter, diesel fuel became more and more expensive as time passed. Thus, operating diesel generators in rural areas is less affordable. This factor motivates the use of alternative power supply options using indigenous renewable energy resources.

Diesel maintenance cost increase – Local power companies purchase spare parts of diesel generators and lubrication materials from abroad and contract payments have to be made in US dollars. However, sales revenue is in Mongolian currency. Due to inflation of the exchange rate of MNT (Mongolian currency) against the US Dollar, costs for maintenance of diesel generators are becoming more and more expensive. As a result, other solutions, such as utilization of renewable energy systems are more attractive in terms of low operating cost and relatively high lifetime.

Difficulty of diesel transportation especially during the winter season – Remotely located soum centres are accessible only through natural off-roads. Mongolia experiences heavy snow fall and strong snow storms during the winter season so roads get blocked by snow. Therefore, it is very difficult to travel or transport goods by truck during the winter time in remote rural areas. People can die due to extreme cold weather in the winter season and it is too risky to transport diesel fuel to the soum centre during the severe weather conditions. This situation can exist between October and April of the next year. Thus, diesel fuel supply can be interrupted, requiring that another possible option for power supply has to be used.

Government's willingness to finance – Although, the Government is facing many challenges related to issues of other sectors and the main economy of the country, it plans to spend some designated funds for development of infrastructure in rural areas, specially power supply systems. However, they should be spent wisely in the future for well prepared renewable energy projects for implementation in rural areas.

Next to world's biggest market – As China is becoming the world's leading country in manufacturing and using renewable energy devices, Mongolia has a good opportunity to import devices from its neighbour country at a reasonable price. Close location also makes it easy to communicate with the manufacturer after installation and get spare parts easily. However, it is necessary to be careful in purchasing renewable energy devices at cheap prices since they can have low quality and a short lifetime. Another common problem is that sometimes all technical documents and manuals are in the Chinese language which is impossible to understand in Mongolia. However, to be next to the world's biggest renewable energy market is a good opportunity for Mongolia.

11. Discussion on the experience of Remote Area Power Supply Systems (RAPS) in other countries

The literature review for this study was mainly focused on experiences in design, installation, operation and management of a similar type and size of renewable-only systems installed at village centres of rural areas in developing countries. Taking into account the consideration of harsh weather conditions, an attempt was made to find information about similar systems installed in two neighboring countries (Russia and China) where in some parts of their territory they have similar weather conditions to Mongolia. However, there was no available information regarding installation and operation of same-sized similar type of systems in Russia, (Martinot 1999). In fact, Russia has not implemented such projects in its rural areas up to now (OECD/IEA 2003). The only project implemented in Russia was a diesel-wind system at a rural area close to the Arctic in the Northern region of the country, but the size of the system was big enough for a town. The project was implemented in cooperation with the National Renewable Energy Laboratory of the USA (Gevorgian and others 1999)

All solar-wind hybrid, solar PV, and wind energy systems that had been installed in the northern territory of China were designated for household use with capacities ranging around 50W - 600W. (Liu and Wang 2009) Therefore, their design and mode of operation are different than the centralized supply type, larger-scale solar-wind hybrid, solar PV and wind only systems installed at centres of soums in rural areas of Mongolia. The capacities of most systems installed at rural village centres in developing countries were 5 - 30 kW and the number of consumers were much less than to the soums centres of Mongolia. The -physical layout of the village centres in other countries also has great differences compared to a Mongolian soum centres' layout. The desktop review covered articles and reports published in the academic literature, studies, and policy related documents regarding technical and non-technical issues of similar type to renewable energy systems.

Many demonstration projects for rural electrification by renewable energy systems have been implemented around the world and millions of dollars have been spent for promotion. However, most of the projects were considered unsuccessful because of the incomplete success in all aspects and issues. For implementation of a successful and sustainable project in rural areas, all relevant aspects must be considered through accurate analysis in order to fulfill the needs of all participating parties throughout the whole lifetime of the renewable energy system (Phillips & Dymond 2000).

The functioning of renewable energy stand-alone systems depends on the weather and geographical conditions at the installation site. Especially, the seasonal climatic changes influence the output of solar PV arrays and wind turbines. Solar-wind hybrid systems alone might not be able to meet the load so that a backup power supply is required for improving the reliability of energy supply. The backup source should not rely or depend on local weather and geographical conditions. A battery bank plays a key role in the functioning of a stand-alone renewable only system, and its state of charge, which is an important parameter which needs to be controlled in a precise way during the operation of the system (Dursun & Kilic 2011 8).

All kinds of stand-alone solar PV systems use a battery bank as an energy storage device. In fact, batteries are expensive, heavy, and have a relatively short lifetime. They require proper regular monitoring and care. However, past experiences from solar PV systems installed in rural areas show that constant provision of monitoring and proper maintenance is difficult to achieve in rural areas. Thus, some solar PV systems were shut down due to failure of the battery bank because of insufficient maintenance and improper monitoring (Manolakos and others 2004 58).

The capacity of renewable energy generators used in stand-alone systems in rural areas would not be sufficient for providing uninterrupted power supply even when the available renewable energy resource is high at that location. The main reason is the periodic variation of the renewable energy resources. Thus, different types of generators should be used to create a hybrid system in order to provide a steady power output. An optimal configuration of the system can reduce the influence of fluctuations by renewable energy resources, raise the output of the system and decrease the size of the energy storage device required. (Ashok 2006 1155)

In the western part of China small-scale solar-wind hybrid systems have been used for street lighting, distributed generation and solar water pumping. Electricity generating capacity of solar only and wind only systems was subject to unforeseeable weather conditions so that by utilizing solar-wind hybrid systems, the fluctuation of output of the renewable energy systems could be reduced to a certain level. However, the most difficult barrier was the low income of the people living in western rural areas of China and the high cost of solar-wind hybrid systems. Thus, from the Government side, special financial assistance is required for people in promoting the use of renewable energy systems in remote rural areas (Liu & Wang 2009 1511).

For renewable energy systems it is difficult to supply all annual loads reliably due to their dependence on weather conditions. The main limitation to the size of renewable energy systems, to provide a reliable power supply for all annual loads, is high upfront cost of PV panels, battery banks, wind turbines and inverters etc. If a small percentage of the annual load is permitted to be unmet, the high initial capital cost can be reduced significantly. It means that the battery bank, PV array, wind turbine are not required to be sized for extreme cases such as overcast days, non-windy days and peak loads. The base load can be supplied from renewable energy systems and 100% reliability of power supply during the peak load can be achieved by running a back-up diesel generator for a few hours. This will give decrease the high initial capital cost of renewable energy systems (Givler and Lilienthal 2005 3).

The cost of the renewable energy systems was too high for poor residents of rural villages in most cases. Insufficiency or lack of standards and training are the main factors for increasing the risks related to poor installations, technical faults, poor maintenance and operation, (UNCTAD 2010 25).

State policies play an essential role in overcoming barriers that form obstacles to successful utilization of renewable energy technologies. Governmental or national policies may support the development of renewable energy, provision of subsidies or financial incentives, implementation of research studies, organization of public awareness campaigns, implementation of demonstration projects and programs, and exemption from import taxes. (UNCTAD 2010 25).

For the development of related standards and accreditation schemes, it is advisable to accept private sector involvement in order to improve the quality of installed renewable energy systems and enhance competition in the installation and maintenance of renewable energy systems. It would enable the renewable energy technology market to become self-sustaining when the government stops providing subsidies. However, in some cases, the level of subsidy provided for promoting the sustainable application of renewable energy technologies in rural areas has not been adequate to attract private sector participation (UNCTAD 2010 26).

The Bergey Excel 7.5 wind turbines (which are manufactured in China was used in most large wind-solar hybrid systems in Mongolia) manufactured by Bergey Windpower Company of the USA were also used in wind-diesel hybrid systems installed in the Northern Territories of Russia. There they operated without any technical problems in the severe weather conditions dominated by cold and snow. All the wind turbines survived at least two winters after their installation. (Gevorgian and others 1999 9).

The Government of Russia developed its "Power Strategy for Russia" in 2004 with an aim of effective utilization of available energy resources, including non-conventional renewable energy resources, which have not been utilized extensively before in remote rural areas where they do not have centralized grid access. As part of this strategy, Russia has been turning its former military bases and weapons factory facilities into factories which manufacture renewable energy devices. A reference catalog of renewable energy devices manufactured in Russia was issued by the Russian Engineering Academy in 2005. The main feature of renewable energy devices manufactured in Russia is that they are designed to work in extremely harsh weather conditions such as Siberia and the Tundra (operating temperature of devices ranges -40 to +50 degrees Celsius) (Bezrukikh 2005). Therefore, in the future, renewable energy devices manufactured in Russia can be used in Mongolia which has similar weather conditions with less technical problems due to harsh weather conditions.

12. Lessons learnt

The lessons learned here are that Mongolia has extreme conditions, both in terms of climatic conditions such as high altitude and low temperatures but also in terms of extreme isolation and difficult installation conditions. Equipment installed in this environment has to have sufficient reliability in operation in remote locations with difficult logistics and installation challenges. If more systems are to be installed they would require stronger local support for operation and maintenance either by a specialized company or through established companies that can expand into this speciality niche. Caution has to be taken with equipment that has a limited record of installations worldwide. Huge distances have to be covered and centralization of all business in Ulaanbaatar city creates logistical barriers to the deployment of small and medium sized renewable energy systems. In order to use commercial renewable energy equipment it is necessary to make sure the support is available locally to install and maintain systems.

The main problems that must be solved in order to improve the functioning of currently installed renewable energy systems were identified as follows:

(i) Hybrid systems installed in the soums were not functioning as an ideal system configuration;

(ii) Quality of the component: quality and performance of system components are generally poor, and some systems are found to have malfunctions and frequent failures;

(iii) Operation and maintenance: since the lifetime of the batteries depends considerably on the operation and maintenance, these must be determined very carefully;

(iv) Electricity quality: large voltage drops and high losses in low voltage distribution lines are found in some soums. Improvements such as a reduction of harmonics and three-phase imbalance is required;

(v) Ownership and management issues need to be clarified

The author is this dissertation has reflected his private opinions for the lesson learnt based on detailed study of the relevant reports and papers on status of 12 renewable energy systems installed in rural soums of Mongolia.

The following specific lessons were learned in process of establishing, constructing, operating, and maintaining of the installed renewable energy systems:

1. Direct contract award method was used without bidding. It was not a good decision to select Contractors without organizing any tender. That means turn-key contracts were made directly with careful selection of the chosen contractors (many had incomplete understanding about what has to be done). The result was the poor performance of the Contractor, as they did not have qualified energy experts, so that installations were made wrongly and some damage occurred due to incorrect installations as a result.

2. Companies selected had insufficient experience. In fact, some of the selected contractors did not have any experience in installation or construction of energy facilities. Thus, there were problems in selecting appropriate devices and equipment. Many mistakes have occurred during the installation process (incorrect connection of solar PV panels, batteries, poor connection of wind turbine guys etc.).

3. Insufficient studies and poor designs. Before construction of any type of energy facilities, a detailed feasibility study is required to be done and the decision to establish renewable energy systems must be taken after consideration of the results of the feasibility study. No feasibility study was previously undertaken at the time of contract conclusion.

4. Insufficient supervision during the installation process by the Client (the National Renewable Energy Centre/Ministry of Mineral Resources and Energy). The Client's specialist had worked only for several times for a limited number of days on a mission to inspect the installation work, which was insufficient to take control of the project at an adequate level. The appointed local control supervisors (as non-professionals they did not have sufficient knowledge and experience) have worked unsatisfactorily.

5. **Wind Turbines were installed in places where feasibility studies and sufficient wind measurements were not conducted.** Out of these 12 hybrid plants, wind measurements were made at only one site over 3 years, which assessed the wind energy resource at a sufficient level. However, for the remaining renewable energy systems, even short-term measurements were not taken, and the assessment of the wind energy resources was not made. Also solar energy resource assessment was not done through measuring solar radiation. It was only based on solar radiation maps and data from other reports.

6. Lower quality of the equipment/components and works done. Most failures occurred on wind turbines and their elements. Almost all renewable energy hybrid systems' controllers malfunctioned. Battery charge and load regulators also have broken several times. Some power cables and batteries were burnt. Wind turbine generator windings were also burnt.

These damages and faults were mainly due to the low quality of the supplied equipment and devices. Some of the wind turbines do not brake to stop the rotor or have an over turning speed protection system.

7. The sizes of the renewable energy systems were not based on the power demand study/forecasts. Although demand was calculated in detail, the size of the hybrid renewable energy systems was not based on the real amount of calculated load. The main explanation given by the National Renewable Energy Centre is that it was mainly due to a limit of the available budget for implementation of these projects. Actually, the budget was cut by the Ministry of Finance during the State Budget formulation process without considering the advice of the experts from the National Renewable Energy Centre (Green Day 2010).

8. Solar, wind and diesel systems are not matched and harmonized to each other to operate as one whole system. Malfunction of one part caused damage to other parts.

9. Diesel generators are not interconnected to the hybrid systems. Existing diesel generators have not been interconnected to the renewable energy plants. Therefore, there is no back-up possibility from a diesel generator in case of load regulator malfunctions. It is also difficult to calculate exactly how much diesel fuel was saved due to utilization of renewable energy plants.

10. Soums could not operate and maintain the hybrid system, especially the control computer system. Currently soum administrations are responsible for operation and maintenance of the installed plants. But most staff have no qualifications and no experience in working on energy systems. Therefore, lack of ownership and management experience by soums governor's offices is the main deficiency.

11. Technical detailed designs were not properly and completely performed. As no solar and wind resource assessments were made at project sites, the design of these renewable energy hybrid systems was made inadequately. For instance, solar panels with different capacities were used to create a series of arrays. No maximum power point tracker was used. Wind turbines were not furnished with dump loads. Solar PV arrays were installed too close to each other so that some arrays were shadowed by other arrays.

12. Unit capacity of the wind turbine is too small and could not withstand a strong wind, wind turbines protecting systems were not sufficient. About 20 wind turbines had broken down (mostly had fallen down) during high wind gusts. In Mongolia, the wind speed often reaches above 25 m/s during the windy period (in Spring and Winter). Some wind blades have been broken down or damaged by strong winds. As some wind turbines do not have a braking system or a rotor turning over-speed protection system, thus generators have fallen from wind turbines, and blades have fallen from the rotor. As the unit capacity of each turbine is small, wind turbines generate much less energy at lower wind speed (they can generate full power only at the rated wind speed which can be reached only sometimes for a short period).

13. Operation and maintenance staff have not been trained and prepared. Sufficient training was not organized. Besides, operation and maintenance manuals were often not provided. Operating staff had not studied the operating manual and did not submit to any exams. Actually, there are no maintenance personnel who carry out regular inspections and minor repair works.

14. Proper operation and management organization was not established. As renewable energy hybrid systems are owned by soum administrations according to the Law of State and Local Property of Mongolia, no separate organization, which is responsible for operation and management (for example, billing and sales revenue collection require special management), has been formed or established. Also no private companies have been involved in these projects. However, in the future, it is absolutely necessary to have a separate entity which has responsibility for proper management and operation of these renewable energy systems, maybe under management contract or concession agreement conditions. Participation of a private company would increase the sustainability of renewable energy systems significantly.

15. Solar PV systems were more reliable than wind systems.

In all cases, solar PV systems were working more steadily and reliably, as they require less maintenance and operational care. But in the Mongolian case, it is necessary to clean arrays after a snowfall. Otherwise, they will not generate any electricity.

16. Functional monitoring and control system should be installed. Control systems of all hybrid systems were not working or did not work reliably. They often had malfunction and due to this, hybrid systems had some technical faults and failures (for instance, wind turbines were not stopped when wind speed reached the cut-off speed, inverters were not disconnected at high load, etc.). Some wind turbines with a brake system did not work due to malfunction of the control system. The most important issue is that operators were unable to control the plants' operation.

17. Regular maintenance and testing of wind turbine components are required: All of these installed wind turbines were not tested in Mongolian conditions before. In the future, they need to be tested in advance under Mongolian conditions and it needs to be verified whether they would work without any problem under Mongolian specific conditions (very cold, dusty, icy and stormy conditions. By taking these considerations into account, special maintenance guidance can be developed.

18. Technical standards are to be observed: Technical standards were followed in designing buildings (heating, ventilation, fire alarms, structural strength, illumination, lightning protection, grounding etc) of the plant. For installation and assembly of renewable energy devices only, current general standards for operation and maintenance of electric equipment was followed. Actually, Mongolia currently does not have any specific standards that can be followed in installation and montage of renewable energy plants. In the future, related standards need to be developed and enforced.

19. Need to implement energy efficiency measures before installation of renewable energy plants: At all soum centres, lighting was the main electricity use. All light bulbs are incandescent lamp,s there is a possibility to reduce the load by replacing them with energy efficient compact fluorescent lights. Consumers need to be aware of the situation that when solar and wind energy resources are at a low level (non-windy or cloudy days), the generation capacity of renewable energy plants will be limited, therefore, they also have to reduce their electricity consumption accordingly.

20. Incorrect, poor quality montage and installations have been done. Solar PV panels were interconnected incorrectly in creating series and arrays. At some hybrid plants the space between two adjacent solar PV arrays was too small so that the solar array standing in front was shadowing the array behind it during some hours of the day. All such installations were corrected by increasing the spaces between arrays by installing another array at a different position (through moving the foundation to another point). Battery poles and terminals were also not connected or incorrectly connected during the installation process.

21. Inappropriate decision for financing - It was stated in the Energy Authority's report that Sevrei soum was connected to the grid and Manlai soum started to operate a diesel generator for 24 hours. In these soums, renewable energy systems have been shut down completely. In other words, they are not using them now however, a large investment was made out of the state budget (about 400 million MNT – Sevrei, 910 million MNT – totalling about 1.075 million AUD) for establishment of these systems. The money spent for these systems could have been used for implementation of other projects or to extend systems, which, had insufficient capacity. Thus, initial decisions for financing should be strictly tied to the future development plan of soums.

13. Conclusions and recommendations

Mongolia has good renewable energy resources. However, available resources have to be assessed before implementing renewable energy projects. Especially, wind energy assessment should be made at the installation site, through measurement devices, for at least a one year period. Thus, wind turbines are only recommended to be installed at sites where wind resource assessment has been a sufficient level of wind resource is available.

Since the collapse of the communist regime, the centralized systematic service provision for the diesel generators operating in rural areas has collapsed. Thus, currently no regular maintenance is available in local areas due to lack of a professional service organization and the low tariff (the revenue is insufficient for carrying out maintenance). Besides, the diesel fuel price has been increasing constantly since the 1990's and now has already exceeded 1.6 $/L in rural areas of Mongolia. Currently, the diesel fuel price in the capital city is 1650 MNT/litre (1.29 $/L) and reaching a price of about 2047 MNT/l (1.64 $/L) in rural areas.

Renewable energy systems (12) installed at rural soum centres of Mongolia in 2007 and 2008 also had a number of technical and non-technical problems. Installation of a renewable energy system is not always the best solution for a power supply issue. Other important issues have to be addressed carefully in order to provide sustainability of the installed renewable energy systems. It is difficult to supply all the load by renewable-only systems due to the magnitude of the load and the difference between minimum and maximum loads. It can be technically possible however, economically it would be very expensive, and more than diesel-only and diesel-renewable generator hybrid systems.

In terms of the key research question, many issues have been identified that will improve the reliability of small-scale renewable energy systems installed in remote areas of Mongolia.

For future projects, it is necessary to provide good preparation in terms of assessing available renewable energy resources and carrying out feasibility studies (for accurate determination of load). The local government and the community have to be involved from the preparation stage in the project implementation process. Operators should be selected in advance so that they have to participate in the installation and commissioning process in order to get a good understanding about the installed system and the villagers needs.

The design of the system has to be done carefully by considering the real load and availability of renewable energy resources. The type of devices should be chosen only upon serious consideration of local harsh weather conditions (for dusty, icy, or snowy areas, and extreme temperatures). For establishment of a good renewable energy system, the allocated budget from the state budget or other resource should be sufficient. In fact, capacities of 12 renewable energy systems installed in Mongolia were too small mainly due to a limited budget. In the future, it should be considered seriously that instead of installing two renewable energy systems with insufficient capacity to cover the load, it is preferable to install only one RE system with sufficient capacity.

Operator training should be organized in a systematic way. At least a simple standard has to be developed and followed. After training, operators should work as assistant operators for at least three months to gain sufficient practical experience and knowledge. After a trial period, a test should be carried out on the criteria to become an operator. It might be difficult to find suitable people from rural areas but this issue should be considered with highest priority, so that operators need to receive some salary even during their training period, and some social issues have to be solved for their steady employment in the future. Some parts of the budget should be spent for this purpose. Contractors should provide full and correct translation of operation and maintenance manuals for the installed systems. English version of manuals should be kept for verification and check up purposes either at the office of the energy plant or in the archive of the soum governor's office.

Currently electricity sale tariffs for stand-alone renewable energy systems are at a low level so that operation and maintenance costs cannot be covered fully. Tariffs should be at a higher level so that renewable energy systems in rural areas should be able to collect enough sales revenue for covering all costs. However, it is constrained by consumers' affordability. Therefore, the Government of Mongolia needs to provide a subsidy from the renewable energy fund in accordance with the Law of Special Funds of Mongolia. It would be a key trigger for sustainable functioning of stand-alone renewable energy systems installed in rural areas.

There are many factors that cause ineffectiveness but one major factor is the lack of sense of ownership of the system. The introduction of new technology does not solve a problem when there is a problem in the management. The successful power supply operation is based on sound management that encourages productivity and quality improvement efforts. Sound management can only be sustained with a strong sense of responsibility.

All 22 soums collect electricity charges on a fixed basis instead of using meters. Soums administrations are generally reluctant to agree to change the tariff system to meter measurement. The main reason is that the administrative workload will be large, and the soum administration would face lack of experience in handling of electricity supply businesses. Power supply units should be separated from soum's main administration, and must have separate accounts. At least a minor restructuring is needed to improve the management. In the future, central and local governments should be required to consider the option of giving renewable energy stand-alone systems to a private professional entity under a management contract or concession agreement, to improve the management and enable sustainable functioning of the power supply systems.

Unenlightened consumers are the major factor that causes some critical technical problems in the installed systems. In fact, the household users would claim that they are saving energy as best as they can, but in reality, many are using heavy load appliances such as electric stoves without much restraint. The consequent high loads of output are forcing the generators to operate excessively and causing much damage. In addition, consumers do not reduce their energy consumption during days when renewable resources are low. Thus, a general public education program has to be organized before implementing renewable energy projects so that consumers would adjust their energy consuming habits according to the weather conditions and the demand-side management will be improved.

Most of the renewable energy devices installed at 12 renewable energy systems such as solar photovoltaic and wind turbines were manufactured in China and designated to be utilized in a warn environment. Solar PVs had fewer problems in a cold environment but wind turbines had the worst problem since their installation. For future installations of renewable energy systems, a specific consideration needs to be taken in selecting renewable energy devices and equipment that can be operated in a harsh continental climate condition. Particularly, devices and equipment that are designed to work at extreme temperature range from -50 to +40 degrees Celsius therefore, devices and equipment manufactured in Russia, the USA, Canada, Scandinavian countries that are designated to be utilized in a cold environment can be used with less problem in Mongolian condition. It is recommended to avoid using renewable energy devices and equipment that are designated to be operated in a warm climate or in countries with mild environment where there are not significant temperature difference between the cold and warm seasons.

Seemingly, from the results of above study, barriers weigh more than drivers for renewable energy development in the rural electrification of Mongolia. Many important lessons were learnt through implementation of the 12 projects. For a sound development of new renewable energy power supply systems at rural soum centres in the future, all associated issues of the post installed renewable energy stand-alone systems must be considered seriously. Systematic careful planning and organization of necessary steps in the implementation stages of a project would ensure the sustainability of the functioning of renewable energy systems in rural soum centres in the future.

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Note: Other two major field reports developed by specialists of Energy Authority of Mongolia (20 pages) and experts of Ministry of Mineral Resources and Energy of Mongolia (30 pages) were translated from Mongolian into English but were not included in the appendixes section. However, these reports can be seen from the DVD which all associated files were recorded.

APPENDIXES

APPENDIX I. Detailed introduction about each soum and projects for establishment of Renewable Energy Systems at the centre of these soums

Ministry of Mineral Resources and Energy of Mongolia

Detailed introduction about each soum and
projects for establishment of
Renewable Energy Systems at the centre of these soums

The Energy Authority of Mongolia

Ulaanbaatar City
February 3, 2010

Translated and compiled by: T. Khishigt, Postgraduate student of Murdoch University
March, 2011

Contents

Bayantsagaan soum of Bayankhongor aimag

Picture. Solar-Wind Hybrid system at the centre of Bayantsagaan soum, Bayankhongor aimag

Energy Authority of Mongolia

Ulaanbaatar City
February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Bayantsagaan soum Bayankhongor aimag
Information about consumers	Households winter/summer	number	250/130
	Number of people winter /summer	number	1500/680
	Organizations	number	7
	Daily peak load, /winter/ by estimation	kW	75
	Daily load – winter season	kWh	703
	Daily load – summer season	kWh	625
	Annual electricity load (by estimation)	kWh	246000
Renewable Energy Resources	Solar	kWh/m^2 annual	1830
	Wind	m/s	4.92

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2006 for electrification of Bayantsagaan soum in Bayankhongor aimag (province).

Table 2. Background information about renewable energy generator

Name, location, installed capacity	150 kW solar-wind hybrid power plant at centre of Bayantsagaan soum of Bayankhongor aimag		
Cost	920,0 million MNT (751020 AUD)	Contract signed date	2007-03-26
Contractor	“Bayanconstruction” Co., Ltd	Contract term	2007-11-30
B. Technical specification of installed main equipment			
Solar PV panels	180 pieces of 160 W, 165W, 170 W solar PV panels manufactured by “Trina solar” Co.,Ltd of China		
Wind turbine	12 pieces of 10 kW wind turbine manufactured by “Beijing bergey windpower” Co.,Ltd of China		
Inverter	MTP-416F type 2 inverters with 60 kW capacity manufactured by Leonics Co., Ltd of Thailand		
Battery	360 pieces of 2 Volt 1000 Ah battery manufactured in China		
Battery charge regulator	SCP-240120 type with control panel box manufactured by Leonics Co., Ltd of Thailand		

Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	30
	Wind		120
	Battery	kWh	720
Capacity of renewable energy		kW	150

generator			
Energy production by the renewable energy generator	Solar	kWh annual	58016
	Wind		98764
	Total		156780
Demand supply rate	Demand	kWh	-89220
	Percentage	%	63.7%

Note: The production was estimated only based on the wind and solar energy resources and technical specification of wind turbine and solar PV modules installed at the soum centre. Due to frequent breakage of wind turbines the estimated energy was not generated. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the hybrid plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the hybrid plant /2009.11.15/	Measures needed for normalizing operation of the plant
Since the technical committee (commissioning) worked in January 2008, 2 wind turbines have fallen down due to a gust (extraordinary strong storm occurred) and the contractor had repaired these two turbines within a short period. However, 3 wind turbines fell down in March 2008. Reason of falling down was that the guys were too loose. Moreover, there was a conclusion that wind turbine blades could not withstand at wind speed over 20 m/s and had broken apart. According to the technical specification of the wind turbine, it was noted that in case of wind speed reaches to 25 m/s the wind turbine must stop electricity generation, must got braked and furled (the turbine should be placed out of the wind stream). However, in reality the wind turbine could not withstand at this condition. Although, Contractor has purchased again the fallen wind turbines, but due to Contractor's mistake made during the installation process the wind turbines have fallen again. Totally 7 wind turbines have fallen and not generating any electricity. After this, between November 2008 and March 2009, there was fire for several times in battery room (which is considered as due to breakage of operation regime) and about 30 batteries had burnt. The emergency department of aimag had extinguished fire and disconnected the main cable (which was under voltage). Operators of hybrid power plant have a poor understanding about the operation manual of the	- need to repair and put into normal operation the broken down 7 wind turbine generators - need to replace the burnt batteries in order to get the voltage of the system to the normal level - Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status - After restoration (repair) of the system, the issue of ownership must be raised to the State Property Committee and get resolved - Necessary to improve the capability of the operating personnel of the hybrid plant. They need involved in the training, and get worked steadily (for a longer period) - Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device - Need to set electricity tariff and collect revenue from consumers regularly

<table>
<tr><td colspan="3">plant. It is required to organize training by the Contractor. Generally speaking, the operators' actual reading and studying the operation manual provided by the contractor is really unsatisfactory.
The anemometer and wind vane was broken down in a strong wind and not working anymore. Also they were not installed at required height.
The operating system (software) of the computer of the data acquisition system is in Chinese language and no data was logged when the anemometer and wind vane were working. Computer of the control system is not working. It is unclear what kind of control software is using. There is no information that contractor had a contract with a professional organization on this issue.
Although, the lighting protection was installed on Solar PV arrays but they were not included in the height of the lighting protection zone (circular area).</td><td>-As it was not possible to supply consumers by wind energy consistently and the currently installed capacity is not enough to supply the demand of the soum the solar PV array's capacity need to be extended by 120 kW
- The people who are interested to work as operator have to read, study all related operation and manual (instructions) in detail that only the person who passes the examination can be selected as an employee.</td></tr>
<tr><td colspan="4">Measures need to be taken in the future</td></tr>
<tr><td colspan="2">Indicators</td><td>Measuring unit</td><td>Comment</td></tr>
<tr><td rowspan="5">To increase or extend the capacity of renewable energy generators</td><td>Solar PV modules</td><td>kW</td><td>120</td></tr>
<tr><td>Wind turbine</td><td>kW</td><td>-</td></tr>
<tr><td>Battery</td><td>kWh</td><td>720</td></tr>
<tr><td rowspan="2">Cost, financing method</td><td rowspan="2">million MNT</td><td>1,400,800,000</td></tr>
<tr><td>In frame of the "Renewable Energy Utilization in electrification of Rural Areas" project of the World Bank which will implemented in 2013-2014 or through utilization of grant aid funds provided by the Asian Development Bank or other donor countries</td></tr>
</table>

Note: The cost of establishing 1 kW solar PV system is 11,680 million MNT (9535 AUD)

Bayan-Undur soum of Bayankhongor aimag

Picture. Solar-wind hybrid power plant at centre of Bayan-Undur soum

Energy Authority

Ulaanbaatar City

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Bayan-Undur soum of Bayankhongor aimag
Information about consumers	Households winter/summer	number	240/135
	Number of people winter /summer	number	618/523
	Organizations	number	16
	Daily peak load, /winter/ by estimation	kW	83
	Daily load – winter season	kWh	820
	Daily load – summer season	kWh	730
	Annual electricity load (by estimation)	kWh	267842
Renewable Energy Resources	Solar	kWh/m^2 annual	1649
	Wind	m/s	5.1

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2006 for electrification of Bayan-Undur soum in Bayankhongor aimag (province).

Name, location, installed capacity			
Cost	920,0 million MNT (751020 AUD)	Contract signed date	2007-03-26
Contractor	"Bayanconstruction" Co., Ltd	Contract term	2007-03-26 2007-11-30

Table 2. Background information about renewable energy generator

Name, location, installed capacity	150 kW solar-wind hybrid power plant at centre of Bayan-Undur soum of Bayankhongor aimag		
Cost	920,0 million MNT (751020 AUD)	Contract signed date	2007-03-26
Contractor	"Bayanconstruction" Co., Ltd	Contract term	2007-03-26 2007-11-30
B. Technical specification of installed main equipment			
Solar PV panels	180 pieces of 160 W, 165W, 170 W solar PV panels manufactured by "Trina solar" Co.,Ltd of China		
Wind turbine	12 pieces of 10 kW wind turbine manufactured by "Beijing bergey windpower" Co.,Ltd of China		
Inverter	MTP-416F type 2 inverters with 60 kW capacity manufactured by Leonics Co., Ltd of Thailand		
Battery	360 pieces of 2 Volt 1000 Ah battery manufactured in China		

Battery charge regulator	SCP-240120 type with control panel box manufactured by Leonics Co., Ltd of Thailand

Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	30
	Wind		120
	Battery	kWh	720
Capacity of renewable energy generator		kW	150
Energy production by the renewable energy generator	Solar	kWh annual	54224
	Wind		125596
	Total		179820
Demand supply rate	Demand	kWh	-88022
	Percentage	%	67.1%

Note: The production was estimated only based on the wind and solar energy resources and technical specification of wind turbine and solar PV modulse installed at the soum centre. Due to frequent breakage of wind turbines the estimated energy was not generated. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the hybrid plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the hybrid plant /2009.11.15/	Measures need to be taken for having a normal operation of the system
Since the State Committee worked (for final acceptance to put into operation) in December 2008 totally 5 wind turbines have fallen down. Also due to not keeping the temperature of the battery room batteries have frozen and got inflated (expanded). Reason of falling down was that the guys were too loose. Moreover, there was a conclusion that wind turbine blades could not withstand at wind speed over 20 m/s and had broken apart. According to the technical specification of the wind turbine, it was noted that in case of wind speed reaches to 25 m/s the wind turbine must stop electricity generation, must got braked and furled (the turbine should be placed out of the wind stream). However, in reality the wind turbine could not withstand at this condition. Although, Contractor has purchased again the fallen wind turbines, but due to Contractor's mistake made during the installation process the wind turbines have fallen again. Totally 7 wind turbines have fallen and not generating any electricity. Operators of hybrid power plant have a poor understanding about the operation manual of the plant. It is required to organize training by the Contractor. Generally speaking, the operators' actual	- need to repair and put into normal operation the broken down 5 wind turbine generators - need to replace the frozen batteries in order to get the voltage of the system to the normal level - Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status - After restoration (repair) of the system, the issue of ownership must be raised to the State Property Committee and get resolved - Necessary to improve the capability of the operating personnel of the hybrid plant. They need involved in the training, and get worked steadily (for a longer period) - Operating personnel are needed to be provided by operation and

reading and studying the operation manual provided by the contractor is really unsatisfactory. Moreover, the spirit of the worker towards the care of the system is insufficient. Work place is dirty, no one cleans solar PV modules when dust, show is covered on them. The anemometer and wind vane were not installed at required height. The operating system (software) of the computer of the data acquisition system is in Chinese language and no data was logged when the anemometer and wind vane were working. Computer of the control system is not working. It is unclear what kind of control software is using. There is no information that contractor had a contract with a professional organization on this issue. Although, the lighting protection was installed on Solar PV arrays but they were not included in the height of the lighting protection zone (circular area).	maintenance manual of each equipment and device - Need to set electricity tariff and collect revenue from consumers regularly -As it was not possible to supply consumers by wind energy consistently and the currently installed capacity is not enough to supply the demand of the soum the solar PV array's capacity need to be extended at least by 120 kW - The people who are interested to work as operator have to read, study all related operation and manual (instructions) in detail that only the person who passes the examination can be selected as an employee. - Operators of the plant need to get habitual in regular cleaning and maintaining of equipment and devices, and areas around the plant

<table>
<tr><td colspan="4">Measures need to be taken in the future</td></tr>
<tr><td colspan="2">Indicators</td><td>Measuring unit</td><td>Comment</td></tr>
<tr><td rowspan="5">To increase or extend the capacity of renewable energy generators</td><td>Solar PV modules</td><td>kW</td><td>120</td></tr>
<tr><td>Wind turbine</td><td>kW</td><td>-</td></tr>
<tr><td>Battery</td><td>kWh</td><td>720</td></tr>
<tr><td rowspan="2">Cost, financing method</td><td rowspan="2">million MNT</td><td>1,400,800,000</td></tr>
<tr><td>In frame of the "Renewable Energy Utilization in electrification of Rural Areas" project of the World Bank which will implemented in 2013-2014 or through utilization of grant aid funds provided by the Asian Development Bank or other donor countries</td></tr>
</table>

Note: The cost of establishing 1 kW solar PV system is 11,680 million MNT (9535 AUD)

Bogd soum in Uvurkhangai aimag

Picture. Wind power plant in Bogd soum of Uvurkhangai aimag

Energy Authority of Mongolia

Ulaanbaatar City

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Bogd soum Uvurkhangai aimag
Information about consumers	Households winter/summer	number	400/250
	Number of people winter /summer	number	2000/1300
	Organizations	number	29
	Daily peak load, /winter/ by estimation	kW	101
	Daily load – winter season	kWh	900.53
	Daily load – summer season	kWh	854
	Annual electricity load (by estimation)	kWh	280000
Renewable Energy Resources	Solar	kWh/m^2 annual	1690
	Wind	m/s	4,5

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2006 for electrification of Bogd soum in Uvurkhangai aimag (province).

Table 2. Background information about renewable energy generator

Name, location, installed capacity	80 kW wind power plant at centre of Bogd soum, Uvurkhangai aimag		
Cost	420,0 million MNT	Contract signed date	2006-11-13
Contractor	"AB Solaar" Co., Ltd	Contract term	2006-11-13 2007-07-15
B. Technical specification of installed main equipment			
Wind turbine	4 pieces of AH-20 type 20 wind turbine manufactured in China		
Inverter	BNX500-31000 type with 100 kW capacity		
Battery	GFM-1200 type 2 Volt 1200 Ah manufactured in China		
Battery charge reg.	-		

Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	0
	Wind		80
	Battery	kWh	325
Capacity of renewable energy generator			80
Energy production by the renewable energy generator	Solar	kWh annual	0
	Wind		93292
	Total		93292
Demand supply rate	Demand	kWh	-186708
	Percentage	%	33.3%

Note: The production was estimated only based on the wind energy resource and technical specification of wind turbines installed at the soum centre. Due to frequent breakage of wind *turbines the estimated energy was not generated. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the plant. Because of this reason, it is impossible to get detailed information about the production.*

Table 4. Current status of renewable energy plant and measures needed in the future

<table>
<tr><td colspan="2">Current status of the plant /2010.02.02/</td><td colspan="2">Measures need to be taken for having a normal operation of the system</td></tr>
<tr><td colspan="2">The State Committee worker on November 17, 2008 for final acceptance. Since then the wind turbine No 2 has fallen down. Before, due to loose tightening of flange bolts the wind turbine No 4 had fallen down.
Due to inconsistent and poor charging the quality of batteries became worsened (deteriorating) gradually.
The heating of battery and power electronic devices room is really poor.
The computer system that enables to see the operation regime of the plant is not working consistently.
Operation and maintenance manual for each equipment and device of the plant for operators usage is insufficient.</td><td colspan="2">- need to repair and put into normal operation the broken down wind turbine generator no 2
- Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status
- After restoration (repair) of the system, the issue of ownership must be raised to the State Property Committee and get resolved
- Necessary to improve the capability of the operating personnel of the wind plant. They need involved in the training, and get worked steadily (for a longer period)
- Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device
- As the demand of the soum cannot be supplied by the renewable energy plant it is necessary to execute the construct overhead transmission line to the neighbouring soum Baruunbayanulaan which is 92 km away from the Bod soum's centre.
- The wind plant is needed to be converted as a gird connected plant and use as a generator to compensate power loss in the interconnected system - Need to set electricity tariff and collect revenue from consumers regularly</td></tr>
<tr><td colspan="4">Measures need to be taken in the future</td></tr>
<tr><td colspan="2">Indicators</td><td>Measuring unit</td><td>Comment</td></tr>
<tr><td rowspan="4">To connect to the central energy system's grid</td><td>Possible voltage of overhead transmission line</td><td>kV</td><td>15</td></tr>
<tr><td>Version</td><td>Text</td><td>To connect from Baruunbayanulaan soum of Uvurkhangai aimag by 15 kV high voltage overhead transmission line</td></tr>
<tr><td>distance</td><td>km</td><td>92</td></tr>
<tr><td>cost, financing method</td><td>Million,₮</td><td>Budget cost is 1380.0 million MNT.
State Budget</td></tr>
</table>

Note: the cost for construction of 1 km 15 kV overhead line is 15.0 million MNT.

Bugat Soum, Govi-Altai aimag

Picture. Solar PV plant in Bugat soum

Energy Authority of Mongolia

Ulaanbaatar city

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Bugat soum Govi-Altai aimag
Information about consumers	Households winter/summer	number	241/134
	Number of people winter /summer	number	710/596
	Organizations	number	17
	Daily peak load, /winter/ by estimation	kW	79
	Daily load – winter season	kWh	725
	Daily load – summer season	kWh	584
	Annual electricity load (by estimation)	kWh	246412
Renewable Energy Resources	Solar	kWh/m^2 annual	1720
	Wind	m/s	4.9

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2006 for electrification of Bugat soum in Govi-Altai aimag (province).

Table 2. Background information about renewable energy generator

Name, location, installed capacity	Initially 60 kW latest (+80 kW) = 140 kW Solar PV plant in Bugat soum, Govi-Altai province		
Cost	1630,0 million MNT (1,330,612.24 AUD)	Contract signed date	2007-03-26
Contractor	"New Power" Co., Ltd	Contract term	2007-03-26 2009-11-30
B. Technical specification of installed main equipment			
Solar PV modules	570 pieces of 175 W module manufactured by "Trina solar" of China		
Inverter	MTP-416F type 2 inverters with 60 kW and 100 kW capacity manufactured by Leonics Co., Ltd of Thailand		
Battery	2 Volt 1000 Ah – 600 pieces battery manufactured in China		
Battery charge regulator	4 pieces of SCP-240120 type with control panel box manufactured by Leonics Co., Ltd of Thailand		

Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	140
	Wind		0
	Battery	kWh	1200
Capacity of renewable energy generator			80
Energy production by the renewable energy generator	Solar	kWh annual	280282
	Wind		0
	Total		280282
Demand supply rate	Demand	kWh	246412
	Percentage	%	87.9%

Note: The production was estimated only based on the solar energy resource and technical specification of solar PV modules installed at the soum centre. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

<table>
<tr><td colspan="2">Current status of the plant</td><td colspan="2">Measures need to be taken for having a normal operation of the system</td></tr>
<tr><td colspan="2">Currently the solar PV plant in Bugat soum centre has installed capacity of 140 kW. Its battery size is 1200 kWh and inverter capacity is 160 kVA. Initially built 60 kW operator’s house was extended.</td><td colspan="2">- Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status
- After completion of the system, the issue of ownership must be raised to the State Property Committee and get resolved
- Necessary to improve the capability of the operating personnel of the solar PV plant. They need involved in the training, and get worked steadily (for a longer period)
- Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device
- Need to set electricity tariff and collect revenue from consumers regularly</td></tr>
<tr><td colspan="4">Measures need to be taken in the future</td></tr>
<tr><td colspan="2">Indicators</td><td>Measuring unit</td><td>Comment</td></tr>
<tr><td rowspan="5">To increase or extend the capacity of renewable energy generators</td><td>Solar PV modules</td><td>kW</td><td>50</td></tr>
<tr><td>Wind turbine</td><td>kW</td><td>-</td></tr>
<tr><td>Battery</td><td>kWh</td><td>720</td></tr>
<tr><td rowspan="2">Cost, financing method</td><td rowspan="2">million MNT</td><td>572,000,000</td></tr>
<tr><td>In frame of the “Renewable Energy Utilization in electrification of Rural Areas” project of the World Bank which will implemented in 2013-2014 or through utilization of grant aid funds provided by the Asian Development Bank or other donor countries</td></tr>
</table>

Khatanbulag soum, Dornogovi aimag

Picture. Wind power plant in Khatanbulag soum

Energy Authority of Mongolia

Ulaanbaatar City

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Khatanbulag soum, Dornogovi aimag
Information about consumers	Households winter/summer	number	128/92
	Number of people winter /summer	number	690/520
	Organizations	number	15
	Daily peak load, /winter/ by estimation	kW	59
	Daily load – winter season	kWh	780
	Daily load – summer season	kWh	590
	Annual electricity load (by estimation)	kWh	178291
Renewable Energy Resources	Solar	kWh/m^2 annual	1930
	Wind	m/s	7.5

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2006 for electrification of Khatanbulag soum in Dornogovi aimag (province).

Table 2. Background information about renewable energy generator

Name, location, installed capacity	150 kW wind power plant in Khatanbulag soum, Dornogovi aimag		
Cost	890,0 million MNT (726530,61 AUD)	Contract signed date	2007-03-26
Contractor	"Mongol Alt" Co., Ltd	Contract term	2007-03-26 2007-11-01

B. Technical specification of installed main equipment

Wind turbine	15 pieces of 10 kW wind turbine generator manufactured in Chingdao city's factory, China
Inverter	WZ150-1 type 480 V 150 kVA capacity
Battery	240 pieces of 2 V, 2000 Ah battery manufactured by Zibo battery factory of China
Battery charge regulator	-

Capacity and type of energy source	Solar	kW	0
	Wind		150
	Battery	kWh	960
Capacity of renewable energy		kW	150

generator			
Energy production by the renewable energy generator	Solar	kWh annual	0
	Wind		252196
	Total		252196
Demand supply rate	Demand	kWh	178291
	Percentage	%	70.69%

Note: The production was estimated only based on the wind energy resource and technical specification of wind turbines installed at the soum centre. Due to frequent breakage of wind turbines the estimated energy was not generated. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the hybrid plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the plant /2010.02.02/	Measures needed for normalizing operation of the plant
The State Committee has accepted the plant on June 25, 2008. The plant operated normally until October 20, 2008. Afterwards, blades of many wind turbines and charge regulators have broken down. The plant lost its controlled operation and transferred into manual operation that the State Inspector had decided to stop the plant until the technical fault is eliminated. The contractor has repaired the fault and repaired blades of wind turbine. However, did not replace all charge regulators. The explanation was that manufacturer did not provide it. Currently only two wind turbines are under repair and the only item needed to be solved is the replacement of charge regulators. The control system that shows main information about the operation status of the plant is not working consistently (often disrupted). Operation and maintenance manual for each equipment and device that should be used by the operator is not sufficient.	- need to repair and put into normal operation the broken down 2 wind turbine generators - Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status - After restoration (repair) of the system, the issue of ownership must be raised to the State Property Committee and get resolved - Necessary to improve the capability of the operating personnel of the plant. They need involved in the training, and get worked steadily (for a longer period) Need to employ initially prepared (trained) people. - Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device - Need to set electricity tariff and collect revenue from consumers regularly -As it was not possible to supply consumers by wind energy consistently and the currently installed capacity is not enough to supply the demand of the soum it is necessary to add solar PV array's on this plant to make it hybrid plant – need to

<table>
<tr><td colspan="3"></td><td>determine the size of solar PV to be added</td></tr>
<tr><td colspan="4">Measures need to be taken in the future</td></tr>
<tr><td colspan="2">Indicators</td><td>Measuring unit</td><td>Comment</td></tr>
<tr><td rowspan="5">To increase or extend the capacity of renewable energy generators</td><td>Solar PV modules</td><td>kW</td><td>120</td></tr>
<tr><td>Wind turbine</td><td>kW</td><td>-</td></tr>
<tr><td>Battery</td><td>kWh</td><td>1200</td></tr>
<tr><td rowspan="2">Cost, financing method</td><td rowspan="2">MNT</td><td>1,400,800,000</td></tr>
<tr><td>In frame of the “Renewable Energy Utilization in electrification of Rural Areas” project of the World Bank which will implemented in 2013-2014 or through utilization of grant aid funds provided by the Asian Development Bank or other donor countries</td></tr>
</table>

Note: The cost of establishing 1 kW solar PV system is 11,680 million MNT (9535 AUD)

Mandakh soum in Dornogovi aimag

Wind –diesel hybrid power plant

Energy Authority of Mongolia

Ulaanbaatar City

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Mandakh soum Dornogovi aimag
Information about consumers	Households winter/summer	number	190/120
	Number of people winter /summer	number	600/450
	Organizations	number	12
	Daily peak load, /winter/ by estimation	kW	75
	Daily load – winter season	kWh	772
	Daily load – summer season	kWh	503
	Annual electricity consumption (by estimation)	kWh	250913
Renewable Energy Resources	Solar	kWh/m^2 annual	1690
	Wind	m/s	6,0

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2005 for electrification of Mandakh soum in Dornogovi aimag (province).

Table 2. Background information about renewable energy generator

Name, location, installed capacity	80 kW wind-diesel hybrid power plant at centre of Mandakh soum, Dornogovi aimag		
Cost	484,0 million MNT (395102 AUD)	Contract signed date	2006-11-13
Contractor	“Prestige engineering” Co., Ltd	Contract term	2006-11-13 2007-07-20

B. Technical specification of installed main equipment	
Wind turbine	Beijing Bergey Wind power B 10XLR type 20 kW - 8 pieces
Inverter	Champion-310 type 80 kW
Battery	GFM-450 type 2 Volt – 450 Ah
Charge regulator	Beijing Bergey Wind power

Table 3. Information about energy generated by the renewable energy system

Capacity and type of energy source	Solar	kW	0
	Wind		80
	Battery	kWh	324
Capacity of renewable energy generator		kW	80
Energy production by the renewable energy	Solar	kWh annual	0
	Wind		154994

generator	Total		154994
Demand supply rate	Demand	kWh	-95919
	Percentage	%	61.8%

Note: The production was estimated only based on the wind energy resource and technical specification of wind turbine. In case of wind power plant in Mandakh soum, when there is no wind the soum become without electricity supply. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the wind turbine and the system worked under this condition for 2 years. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the wind energy plant /2010.02.02/	Measures need to be taken for having a normal operation of the system
Since the State Committee worked to accept the plant for its final hand over it was found out that due to manufacturing defect the state of charge level of 24 batteries has declined. The contractor "Prestige Engineers has replaced these batteries. The computer based control system that shows the electricity generation by the wind turbine-generator and the wind speed was broken down since 2009 and not repaired until today. But the warranty period given by the Contractor is finished. Due to limited hours of operation of the diesel generator the condition of batteries started to deteriorate. Although, it is called as wind-diesel hybrid system in fact diesel never works with the wind turbine. The estimation shows that the if diesel is operated with the wind system (for different hours depending on the load condition) then the cost of electricity generator by the diesel generator would be 600 MNT per kWh (48.9 cents of AUD) then it is not affordable and considered as impossible option.	- Need to repair and restore the computer-based control system - Need to set electricity tariff and regularly collect the revenue (bill) from the consumers - Although, wind energy system works normally, the system completely stops during the non-windy period (no electricity supply to during this period). But the electricity demand is increasing as time passes therefore, the currently installed system cannot supply all demand continuously in and stable manner. Therefore, it became necessary to establish a solar PV system to supply the growing electricity demand. However, this needs a considerable investment.

Manlai soum Umnugovi aimag

Pciture. Solar-Wind hybrid power plant at the centre of Manlai soum, Umnugovi aimag

Energy Authority of Mongolia

Ulaanbaatar City

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Manlai soum, Umnugovi
Information about consumers	Households winter/summer	number	160/122
	Number of people winter /summer	number	560/489
	Organizations	number	16
	Daily peak load, /winter/ by estimation	kW	65
	Daily load – winter season	kWh	897
	Daily load – summer season	kWh	566
	Annual electricity load (by estimation)	kWh	246221
Renewable Energy Resources	Solar	kWh/m^2 annual	2000
	Wind	m/s	5.9

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2006 for electrification of Manlai soum in Umnugovi aimag (province).

Table 2. Background information about renewable energy generator

Name, location, installed capacity	Solar-Wind hybrid power plant at centre of Manlai soum, Umnugovi aimag		
Cost	910,0 million MNT (742857AUD)	Contract signed date	2007-03-26
Contractor	"Uureg " Co., Ltd	Contract term	2007-03-26 2007-11-30
B. Technical specification of installed main equipment			
Solar PV panels	166 pieces of 180 W solar PV module manufactured by the "Trina solar" of China		
Wind turbine	12 pieces of 10 kW wind turbine generator manufactured by "Tairui wind power" Co. Ltd of China		
Inverter	Two inverters with each of 75 kW and 150 kW capacity manufacture by Nanjing first second power equipment of China		
Battery	360 pieces of 2 Volt 1000 Ah battery manufactured in China		
Battery charge regulator	DC500V/AC380V 150kW		

Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	30
	Wind		120
	Battery	kWh	720

Capacity of renewable energy generator		kW	150
Energy production by the renewable energy generator	Solar	kWh annual	60060
	Wind		177573
	Total		237633
Demand supply rate	Demand	kWh	-8588
	Percentage	%	96.5%

Note: The production was estimated only based on the wind and solar energy resources and technical specification of wind turbine and solar PV modules installed at the soum centre. Due to frequent breakage of wind turbines the estimated energy was not generated. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the hybrid plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the hybrid plant /2009.11.15/	Measures needed for normalizing operation of the plant
The Working Committee has accepted the plant on December 25, 2007. Since then, charge regulators of wind turbines have broken down during a strong wind period, The oil in the brake reduction gear was frozen. Thus. The plant was not operated steadily. However, the soum's consumers were not disconnected completely. At a certain level, the plant supplied organizations in the soum centre. Interesting fact that an animal lives in underground called zag's rat had food deficiency and have eaten control cables (cables between the sensors and data acquisition system) and even power cables (sometimes they caused short circuit). After repair of these breakages, there occurred another fault due to a human factor. In March 2009, German experts went there and due to misunderstanding between the operator and the foreign experts, the operator disconnected a loaded power line and as a result all charge regulators of wind turbines, 1 inverter, and some batteries have burnt out. The Contractor paid much attention in replacing the damaged parts and the repair work was finished November 2009 and it became possible to operate the plant. But, there was another similar damage due to zag's rats eating of the cables. Also due to the situation that the operator Puntsagbold has operated the plant without load thus the contractor has fully shut down the plant. Now it is ready to hand over the plant to the State Committee. As for the Manlai soum it receives diesel fuel from Oyu-Tolgoi (one of the biggest cuprum deposit in the world) thus operating	- need to repair and put into normal operation the broken down 3 wind turbine generators - Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status - After restoration (repair) of the system, the issue of ownership must be raised to the State Property Committee and get resolved - Necessary to improve the capability of the operating personnel of the hybrid plant. They need involved in the training, and get worked steadily (for a longer period) - Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device - Need to set electricity tariff and collect revenue from consumers regularly -As it was not possible to supply consumers by wind energy consistently and the currently installed capacity is not enough to supply the demand of the soum

its diesel generator for 24 hours. This situation leads to careless operation and non-take care of the renewable energy plant. The current operating personnel has not attended training organized at the National Renewable Energy Centre and did not work during the construction of the plant. The initially trained person was fired by the administration of the soum (which was not based on a reason). Also the operators did not use the computer of control system (the software) which controls the working regime of the plant.	the solar PV array's capacity need to be extended by 120 kW

Measures need to be taken in the future			
Indicators		Measuring unit	Comment
To increase or extend the capacity of renewable energy generators	Solar PV modules	kW	120
	Wind turbine	kW	-
	Battery	kWh	720
	Cost, financing method	million MNT	1,400,800,000
			In frame of the "Renewable Energy Utilization in electrification of Rural Areas" project of the World Bank which will implemented in 2013-2014 or through utilization of grant aid funds provided by the Asian Development Bank or other donor countries

Note: The cost of establishing 1 kW solar PV system is 11,680 million MNT (9535 AUD)

Matad soum, Dornod aimag

Picture. Solar-Wind hybrid plant of Matad soum

Energy Authority of Mongolia

Ulaanbaatar City

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Matad soum, Dornod aimag
Information about consumers	Households winter/summer	number	209/170
	Number of people winter /summer	number	688/483
	Organizations	number	13
	Daily peak load, /winter/ by estimation	kW	68
	Daily load – winter season	kWh	700
	Daily load – summer season	kWh	599
	Annual electricity load (by estimation)	kWh	210020
Renewable Energy Resources	Solar	kWh/m^2 annual	1750
	Wind	m/s	6.5

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2006 for electrification of Matad soum in Dornod aimag (province).

Table 2. Background information about renewable energy generator

Name, location, installed capacity	120 kW Solar-Wind hybrid power plant at centre of Matad soum, Dornod aimag		
Cost	890.0 million MNT (726530 AUD)	Contract signed date	2007-03-26
Contractor	"Bayanconstruction" Co., Ltd	Contract term	2007-03-26 2007-10-25
B. Technical specification of installed main equipment			
Solar PV panels	180 pieces of 160 W, 165W, 170 W solar PV panels manufactured by "Trina solar" Co.,Ltd of China		
Wind turbine	9 pieces of 10 kW wind turbine manufactured by "Beijing bergey windpower" Co., Ltd of China		
Inverter	MTP-416F type 2 inverters with 60 kW capacity manufactured by Leonics Co., Ltd of Thailand		
Battery	360 pieces of 2 Volt 1000 Ah battery manufactured in China		
Battery charge regulator	SCP-240120 type with control panel box manufactured by Leonics Co., Ltd of Thailand		

Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	30
	Wind		90
	Battery	kWh	720
Capacity of renewable energy generator			120

Energy production by the renewable energy generator	Solar	kWh annual	52377
	Wind		151275
	Total		203652
Demand supply rate	Demand	kWh	210020
	Percentage	%	97.0%

Note: The production was estimated only based on the wind and solar energy resources and technical specification of wind turbine and solar PV modules installed at the soum centre. Due to frequent breakage of wind turbines the estimated energy was not generated. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the hybrid plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the hybrid plant /2010.02.02/	Measures needed for normalizing operation of the plant
Currently 3 wind turbines, 30 kW of solar PV are working. 4 wind turbines have broken apart by generator section. 1 wind turbine generator has fallen down completely with its tower. 1 wind turbine's only blades have been broken and fell down. The hybrid plant is supplying electricity to organizations during daytime. Households get electricity in the evening for 3-6 hours. 2 people working at the plant. One of them paid by the contractor Bayanconstruction, another is paid by the Governorls office of the soum. The computer of the control system which reports the working regime of the plant is not used. Although, the low voltage overhead distribution line of soum centre was renovated and installed meters at each consumer, the electricity tariff has not been set. Therefore, people consuming electricity inefficiently without any control.	- need to repair and put into normal operation the broken down 6 wind turbine generators - Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status - After restoration (repair) of the system, the issue of ownership must be raised to the State Property Committee and get resolved - Necessary to improve the capability of the operating personnel of the hybrid plant. They need involved in the training, and get worked steadily (for a longer period) - Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device -As the electricity demand is been growing the solar PV array's capacity need to be extended by 80 kW - Need to set electricity tariff and collect revenue from consumers regularly

Measures need to be taken in the future			
Indicators		Measuring unit	Comment
To	Possible voltage for	kV	15

connect to centralized grid system	transmission line		
	version	Text	If the Daichin Tamsag Petroleum Company will be connected to the Choibalsan Thermal Power Plant by 110 kW high voltage transmission line it is possible to connect Matad soum from there through 80 km length 15 kV overhead high voltage transmission line.
	distance	Km	80
	Cost, financing method	Million MNT	Budget cost is 1,200,0 million MNT State budget + Remaining fund from the contract of Bayanconstruction which executed the solar-wind hybrid plant.

Note: The cost for constructing 1 km of 15 kV overhead transmission line is 15.0 million MNT.

Sevrei soum Umnugovi aimag

Picture. Wind power plant in Sevrei soum

Energy Authority of Mongolia

Ulaanbaatar City

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Sevrei soum Umnugovi aimag
Information about consumers	Households winter/summer	number	160/110
	Number of people winter /summer	number	640/450
	Organizations	number	17
	Daily peak load, /winter/ by estimation	kW	62
	Daily load – winter season	kWh	699
	Daily load – summer season	kWh	644
	Annual electricity load (by estimation)	kWh	228502
Renewable Energy Resources	Solar	kWh/m^2/year	1660
	Wind	m/s	8.6

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2005 for electrification of Sevrei soum in Umnugovi aimag (province).

Table 2. Background information about renewable energy generator

Name, location, installed capacity	80 kW wind power plant in Sevrei soum of Umnugovi aimag		
Cost	395,0 million MNT (322449 AUD)	Contract signed date	2006-11-13
Contractor	"AB Solaar" Co., Ltd	Contract term	2006-11-13 2007-07-15
B. Technical specification of installed main equipment			
Wind turbine	4 pieces of AH-20 type 20 kW wind turbine generator		
Inverter	BNX500-31000 type 100 kW capacity		
Battery	GFM-1200 type 2 Volts 1200 Ah		
Battery charge regulator	-		

Supervision during the construction work of the plant

1. Number of official letters sent to the Contractor – 20
2. Number of meetings held – 10
3. Number of missions to the project site – 16 times (totally 130 days and 43 people /experts/)

Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	0
	Wind		80
	Battery	kWh	325
Capacity of renewable energy generator		kW	80
Energy production by the renewable energy generator	Solar	kWh annual	0
	Wind		150740
	Total		150740
Demand supply rate	Demand	kWh	228502
	Percentage	%	66.0%

Note: The production was estimated only based on the wind energy resource and technical specification of wind turbines installed at the soum centre. Due to frequent breakage of wind turbines the estimated energy was not generated. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the plant /2010.02.02/	Measures needed for normalizing operation of the plant
There is no phase protection at this plant that inverters were burnt out for several times due to difference between phases. Batteries have not been charged sufficiently that their condition is deteriorating gradually. The wind power was supplying 10 kW power to the heating boiler of soum centre, and also supplying other organizations at the soum centre. Currently, the plant is shut down fully. The heating of the building where batteries, power electronics installed is at a very poor level. The computer based control system is not working stable. It is necessary to provide operation and maintenance manual to the operators who are working at the plant.	- Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status - After restoration (repair) of the system, the issue of ownership must be raised to the State Property Committee and get resolved - Necessary to improve the capability of the operating personnel of the wind plant. They need involved in the training, and get worked steadily (for a longer period) - Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device - As the wind power plant could not supply all demand solely, the Sevrei soum's centre should be connected to neighbouring Noyon soum's centre (which is about 56 km away) through overhead high voltage transmission line _Then the wind power has to be converted into a grid connected plant that help to the grid system to reduce the loss of the system - Need to set electricity tariff and collect revenue from consumers regularly

Measures need to be taken in the future		
Indicators	Unit	Comment

To connect to the centralized grid	Possible voltage for overhead high voltage transmission line	kV	15
	Version	Text	To connect Sevrei soum from Noyon soum of Umnugovi province through 15 kV high voltage transmission line
	Distance	km	56
	Cost, financing method	million MNT	Budget cost is 840,0 million MNT. State budget. It is also possible to agree with the company Chinhua Mak Co., Ltd which is currently performing mining activity in the local area.

Note: The cost for constructing 1 km length 15 kV overhead high voltage transmission line is 15,0 million MNT.

Shinejinst soum of Bayanhongor aimag

Picture. Solar-Wind hybrid plant of Shinejinst soum

Energy Authority of Mongolia

Ulaanbaatar City
February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Shinejinst soum of Bayanhongor aimag
Information about consumers	Households winter/summer	number	164/73
	Number of people winter /summer	number	780/290
	Organizations	number	15
	Daily peak load, /winter/ by estimation	kW	59
	Daily load – winter season	kWh	607
	Daily load – summer season	kWh	491
	Annual electricity load (by estimation)	kWh	207216
Renewable Energy Resources	Solar	$kWh/m^2/year$	1820
	Wind	m/s	4.91

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2006 for electrification of Shinejinst soum in Bayankhongor aimag (province).

Table 2. Background information about renewable energy generator

Name, location, installed capacity	150 kW solar-wind hybrid plant at centre of Shinejinst soum, Bayankhongor aimag		
Cost	920,0 million MNT	Contract signed date	2007-03-26
Contractor	"Bayanconstruction" Co., Ltd	Contract term	2007-03-26 2007-11-30
Organization developed engineering design		"Erchim tosol" engineering Co., Ltd	
Data of approval of project documentation by the state expertise		July 5, 2007	
Committee working dates	Technical committee worked on June 29, 2008 Working committee worked on September 25, 2008 State committee worked on December 24, 2008		
B. Technical specification of installed main equipment			
Wind turbine	180 pieces of "Trina solar" type solar PV panels with unit capacity of 160 W, 165 W, 170 W		
Inverter	12 pieces of 10 kW Wind turbine manufactured by "Beijing Bergey Windpower Co., Ltd " Co.,Ltd		
Battery	Two inverters MTP-416F type with each of 60 kW capacity manufactured by Leonics LLC of Thailand		
Battery charge regulator	360 pieces of 2V 1000Ah capacity batteries manufacture in China		
Wind turbine	SCP-240120 type manufactured by Leonics LLC of Thailand with		

charge controller	control panel

Supervision during the construction work of the plant

1. Number of official letters sent to the Contractor – 25
2. Number of meetings held – 10
3. Number of missions to the project site – 17 times (totally 140 days and 36 people /experts/)

Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	30
	Wind		120
	Battery	kWh	720
Capacity of renewable energy generator		kW	150
Energy production by the renewable energy generator	Solar	kWh annual	54612
	Wind		87612
	Total		142224
Demand supply rate	Demand	kWh	-64992
	Percentage	%	68.6%

Note: The production was estimated only based on the wind and solar energy resources and technical specification of wind turbine and solar PV modulse installed at the soum centre. Due to frequent breakage of wind turbines the estimated energy was not generated. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the hybrid plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the hybrid plant /2009.11.15/	Measures need to be taken for having a normal operation of the system
Since the State Committee worked (for final acceptance to put into operation) in December 2008 totally 9 wind turbines have fallen down. Also, the temperature of battery room was not maintained at the required degree that batteries have frozen and their shape became swollen. Reason of falling down of wind turbines was that the guys were too loose. Moreover, there was a conclusion that wind turbine blades could not withstand at wind speed over 20 m/s and had broken apart. According to the technical specification of the wind turbine, it was noted that in case of wind speed reaches to 25 m/s the wind turbine must stop electricity generation, must got braked and furled (the turbine should be placed out of the wind stream).	- need to repair and put into normal operation the broken down 7 wind turbine generators - need to replace the frozen batteries in order to get the voltage of the system to the normal level - Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status - After restoration (repair) of the system, the issue of ownership must be raised to the State Property Committee and get resolved - Necessary to improve the

However, in reality the wind turbine could not withstand at this condition. Although, Contractor has purchased again the fallen wind turbines, but due to Contractor's mistake made during the installation process the wind turbines have fallen again. Totally 7 wind turbines have fallen in such ways and not generating any electricity. Operators of hybrid power plant have a poor understanding about the operation manual of the plant. It is required to organize training by the Contractor. Generally speaking, the operators' actual reading and studying the operation manual provided by the contractor is really unsatisfactory. Moreover, the spirit of the worker towards the care of the system is insufficient. Work place is dirty, operators clean solar PV modules when dust, show is covered on them only after required. The anemometer and wind vane were not installed at required height. The operating system (software) of the computer of the data acquisition system is in Chinese language and no data was logged when the anemometer and wind vane were working. Computer of the control system is not working. It is unclear what kind of control software is using. Although, the lighting protection was installed on Solar PV arrays but they were not included in the height of the lighting protection zone (circular area).	capability of the operating personnel of the hybrid plant. They need involved in the training, and get worked steadily (for a longer period) - Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device - Need to set electricity tariff and collect revenue from consumers regularly -As it was not possible to supply consumers by wind energy consistently and the currently installed capacity is not enough to supply the demand of the soum the solar PV array's capacity need to be extended at least by 120 kW - The people who are interested to work as operator have to read, study all related operation and manual (instructions) in detail that only the person who passes the examination can be selected as an employee. - Operators of the plant need to get habitual in regular cleaning and maintaining of equipment and devices, and areas around the plant

<table>
<tr><td colspan="4">Measures need to be taken in the future</td></tr>
<tr><td colspan="2">Indicators</td><td>Measuring unit</td><td>Comment</td></tr>
<tr><td rowspan="5">To increase or extend the capacity of renewable energy generators</td><td>Solar PV modules</td><td>kW</td><td>120</td></tr>
<tr><td>Wind turbine</td><td>kW</td><td>-</td></tr>
<tr><td>Battery</td><td>kWh</td><td>720</td></tr>
<tr><td rowspan="2">Cost, financing method</td><td rowspan="2">million MNT</td><td>1,400,800,000</td></tr>
<tr><td>In frame of the "Renewable Energy Utilization in electrification of Rural Areas" project of the World Bank which will implemented in 2013-2014 or through utilization of grant aid funds provided by the Asian Development Bank or other donor countries</td></tr>
</table>

Note: The cost of establishing 1 kW solar PV system is 11,680 million MNT (9535 AUD)

Tseel soum of Govi-Altai aimag

<u>Picture. Solar-wind hybrid plant installed at centre of Tseel soum</u>

Energy Authority of Mongolia

Ulaanbaatar City

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Tseel soum, Govi-Altai aimag
Information about consumers	Households winter/summer	number	243/154
	Number of people winter /summer	number	730/450
	Organizations	number	15
	Daily peak load, /winter/ by estimation	kW	80
	Daily load – winter season	kWh	910
	Daily load – summer season	kWh	852
	Annual electricity load (by estimation)	kWh	254345
Renewable Energy Resources	Solar	kWh/m^2 annual	1880
	Wind	m/s	3.9

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2006 for electrification of Tseel soum in Govi-Altai aimag (province).

Table 2. Background information about renewable energy generator
Table 2. Background information about renewable energy generator

Name of system, location, capacity	150 kW solar-wind hybrid system installed at centre of Tseel soum in Govi-Altai aimag		
Phone numbers:	Contractor	Kh. Enkhjargal Phone: 99118215	
	Governor of the soum	Ts.Batbayar Phone: 99763142	
	Operator	н.Shukher Phone:	
Decision approved the budget	Budget law of Mongolia for year 2007		
Budget cost	960.0 million MNT	Contract signed date	2007-03-26
Contractor	Khurd LLC	Contract term	2007-03-26 2007-11-30

A. Information about financing

Contract price	890.0 million MNT	Remained financing	95,278.9 million MNT

-	Downpayment	Perform. 1	Perform. 2	Perform. 3	Perform. 4	Remark
Date	2007.05.18	2007.10.10	2007.12.02	2007.12.28	2007.12.26	-
Financing	282,300.00	299,000.00	196,000.00	159,400.00	3,348.00	-
Supervisi	5,700.00	10,600.00	4,000.00	-	-3,348.00	-

on						

Organization developed detailed design	CB Engineering design LLC
State Expertise approval date	September 14, 2007
Committee working status	Technical committee worked on November 24, 2007 State Committee worked on December 25, 2007
B. Technical specification of installed main equipment	
Solar PV panels	130 W Keosera type PV panel manufactured in Japan – 230 pieces
Wind turbine	20 kW AH-20 type wind turbine generator manufactured in China – 6 pieces
Inverter	2 pieces of inverters type Leonics MTP-416F manufactured in Thailand – each of 60 kW capacity
Battery	2V 800 Ampere hour capacity – 500 pieces
Battery charge regulator	DC500V/AC380V 120kW

Table 3. Information about energy generation by the renewable energy system
Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	30
	Wind		120
	Battery	kWh	840
Capacity of renewable energy generator		kW	150
Energy production by the renewable energy generator	Solar	kWh annual	60060
	Wind		86139
	Total		146199
Demand supply rate	Demand	kWh	-108146
	Percentage	%	57.5%

Note: The production was estimated only based on the wind and solar energy resources and technical specification of wind turbine and solar PV modules installed at the soum centre. Due to frequent breakage of wind turbines the estimated energy was not generated. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the hybrid plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the hybrid plant /2009.11.15/	Measures needed for normalizing operation of the plant
6 wind turbines, solar panels, and operator's building was repaired. After the repair work 3 wind turbines and 30 kW solar PV panels are working. The system is working totally by 90 kW capacity. 3 wind turbines with each of 20 kW rated capacity had	- need to repair and put into normal operation the broken down 3 wind turbine generators - Need to put into operation

<table>
<tr><td colspan="3">crack on the main casing of electric generators that it was decided by technical committee not to operate these turbines and gave task to Contractor to replace these generators. Solar PV panels interconnecting cable's cross sectional area was increased. The Contractor requested not to operate 1 wind turbine due to its defective in its tail section which was permitted by Technical committee. Currently 2 people working at the system as operator but they have not attended training organized at the National Renewable Energy Centre and did not presence during the installation work. The administrative managers of soum had fired the people used to work at system before. But, the Contractor Khurd LLC sometimes send those people who used to work at the system for carrying out regular inspection and maintenance of the system.
Also the software which has function to inform about the operating status of the system is not working.
Although the low voltage overhead distribution network was rehabilitated and new electricity meters have been installed, electricity is used without any saving or efficiently due to the fact that tariff for electricity has not been set.
When it is windy 3 wind turbines together with solar PV panels can supply the total demand of soum's centre fully. Depending from the brake functioning of wind turbine and quality of wind turbine blades the system could not work steadily due to frequent defects and breakage.</td><td>the control acquisition system that shows electricity generation and renewable energy resources level status
- After restoration (repair) of the system, the issue of ownership must be raised to the State Property Committee and get resolved
- Necessary to improve the capability of the operating personnel of the hybrid plant. They need involved in the training, and get worked steadily (for a longer period)
- Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device
- Need to set electricity tariff and collect revenue from consumers regularly
- In fact, the wind energy utilization is not providing a stable and reliable electricity supply to the consumers
the solar PV panels capacity need to be extended by 120 kW</td></tr>
<tr><td colspan="4">Measures need to be taken in the future</td></tr>
<tr><td colspan="2">Indicators</td><td>Measuring unit</td><td>Comment</td></tr>
<tr><td rowspan="5">To increase or extend the capacity of renewable energy generators</td><td>Solar</td><td>kW</td><td>120</td></tr>
<tr><td>Wind</td><td>kW</td><td>-</td></tr>
<tr><td>Battery</td><td>kWh</td><td>720</td></tr>
<tr><td rowspan="2">Cost, financing method</td><td rowspan="2">Million MNT</td><td>1,400,800,000</td></tr>
<tr><td>It is possible in frame of the "Renewable Energy Utilization in electrification of Rural Areas" project of the World Bank which will implemented in 2013-2014 or through utilization of grant aid funds provided by the Asian Development Bank or other donor countries</td></tr>
</table>

Note: Cost to establish 1 kW solar PV system is 11,680 million MNT.

Tsetseg soum of Khovd aimag

Picture.Solar PV system installed centre of Tsetseg soum in Khovd aimag

Energy Authority of Mongolia

Ulaanbaatar City

February 3, 2010

Table 1. Background information about number of people and electricity demand of soum centre

Indicators		Measuring unit	Tsetseg soum, Khovd aimag
Information about consumers	Households winter/summer	number	210/160
	Number of people winter /summer	number	670/470
	Organizations	number	14
	Daily peak load, /winter/ by estimation	kW	76
	Daily load – winter season	kWh	713
	Daily load – summer season	kWh	533
	Annual electricity load (by estimation)	kWh	235593
Renewable Energy Resources	Solar	kWh/m^2 annual	1360
	Wind	m/s	3.2

Note: The information about number of people living at soum centre, electricity demand, and renewable energy sources was taken from the feasibility study(technical-economical estimation) worked out in 2005 for electrification of Tsetseg soum in Khovd aimag (province).

Table 2. Background information about renewable energy generator

Table 2. Background information about renewable energy generator

Name of system, location, capacity	100 kW Solar PV systems Tsetseg soum, Khovd aimag					
Phone numbers	Contractor	Baasansuren Phone: 99089316				
	Governor	Munkhtur Phone				
	Operator	Altankhuyag Phone: 98009838				
Decision approved the budget	Budget law of Mongolia for year 2006 and 2007					
Budget cost	1175.0 million MNT	Contract signed date	2006-11-13			
Contractor	New Power LLC	Contract term	2006-11-13 2007-10-01			
A. Information about financing						
Contract price	1175.0 Million MNT	Remained financing	22.7 Million MNT			
-	Dowpayment	Perform.1	Perform. 2	Perform.3	Perform.4	Final
Date	2006.12.7	2007.02.23	2007.05.18	2007.10.04	2007.12.28	2008.12.20
Financing	20,500.00	3,220.00	141,800.00	183,100.00	34,620.00	5,000.00
Supervision	-	480.00	2,800.00	2,000.00	1,480.00	-

Organization developed detailed design	JNS design LLC
State Expertise approval date	November 12, 2007
Committee working status	- Technical committee worked on January 19, 2008, - Working committee worked on November 23, 2008 - State committee worked on November 23, 2008
B. Technical specification of installed main equipment	
Solar PV panels	570 pieces of Trina solar type PV panels 175 W manufactured in China
Inverter	2 pieces of inverters type Leonics MTP-416F manufactured in Thailand – each of 60 kW capacity
Battery	360 pieces of 2 V 1000 Ah capacity
Battery charge regulator	SCP-240120 type with control box manufactured by Leonics Co., Ltd of Thailand

Table 3. Information about energy generation by the renewable energy system

Table 3. Information about energy generation by the renewable energy system

Capacity and type of energy source	Solar	kW	100
	Wind		0
	Battery	kWh	1200
Capacity of renewable energy generators		kW	100
Energy production by the renewable energy generator	Solar	kWh annual	200202
	Wind		0
	Total		200202
Demand supply rate	Demand	kWh	-35391
	Percentage	%	85.0%

Note: The production was estimated only based on the solar energy resource and technical specification of solar PV modules installed at the soum centre. The lack of information about the real production is due to breakage of the computer control system that shows the electricity generated by the plant. Because of this reason, it is impossible to get detailed information about the production.

Table 4. Current status of renewable energy plant and measures needed in the future

Current status of the plant /2010.02.02/	Measures need to be taken for having a normal operation of the system
The solar PV plant in Tsetseg soum's centre has installed capacity of 100 kW. The system is operating normally and good. The solar PV arrays were tilted at 60 degrees and the distance between two array rows was 6 meters that the arrays in the rear row was shadowed during the winter time. It was fixed through removing and re-installing at different location and the distance between rows of arrays became 14 meters.	- Need to put into operation the control acquisition system that shows electricity generation and renewable energy resources level status - After completion of the system, the issue of ownership must be raised to the State Property Committee and get resolved

<table>
<tr><td>However, the circuit which will transfer signal from controller and inverter to control computer has not been assembled that it is necessary to be mounted.
It is necessary to focus on organizing more training for operators particularly training on diagnosis of inverter's problem, maintenance and adjustment of inverter, operation of batteries, on main theory of electric law and circuit, on operation of electric facilities and adjustment.
The heating of the rooms where power electronic device and batteries have been installed is at a poor level.
It is necessary to provide the stable operation of the computer system that shows the operation of the solar PV system .
The maintenance manual dedicated for operators for taking care of the installed equipment and devices is insufficient.</td><td>- Necessary to improve the capability of the operating personnel of the solar PV plant. They need involved in the training, and get worked steadily (for a longer period)
- Operating personnel are needed to be provided by operation and maintenance manual of each equipment and device
- As the currently installed system cannot supply fully the demand of soum centre that in future the soum is required to expand the capacity of solar PV system
- Need to set electricity tariff and collect revenue from consumers regularly</td></tr>
</table>

<table>
<tr><th colspan="4">Measures need to be taken in the future</th></tr>
<tr><th colspan="2">Indicators</th><th>Measuring unit</th><th>Remarks</th></tr>
<tr><td rowspan="4">To connect to centralized grid</td><td>Possible voltage of transmission line</td><td>kV</td><td>15</td></tr>
<tr><td>Option</td><td>Text</td><td>In case, the Khoshoot coal mine operating in territory of this soum will be connected to the Western Energy System then it is possible to connect the centre of this soum through 10 kV transmission line with 22 km length.</td></tr>
<tr><td>Distance</td><td>km</td><td>22</td></tr>
<tr><td>Cost, financing method</td><td>Million MNT</td><td>Investment is 246.4 million MNT State Budget and also possible to be implemented by Khoshoot coal mine company.</td></tr>
<tr><td rowspan="5">To expand the capacity of renewable energy generators</td><td>Solar</td><td>kW</td><td>50</td></tr>
<tr><td>Wind</td><td>kW</td><td>-</td></tr>
<tr><td>Battery</td><td>kWh</td><td>720</td></tr>
<tr><td rowspan="2">Cost, financing method</td><td rowspan="2">Million MNT</td><td>572,000,000</td></tr>
<tr><td>In frame of the "Renewable Energy Utilization in electrification of Rural Areas" project of the World Bank which will implemented in 2013-2014 or through utilization of grant aid funds provided by the Asian Development Bank or other donor countries</td></tr>
</table>

Note: The cost of establishing 1 kW solar PV system is 11,680 million MNT (9535 AUD)

APPENDIX II. Actual electricity generation data of installed 12 renewable energy systems in rural soum centres of Mongolia

[redacted]

APPENDIX III. Detailed cost information of wind only system installed at Mandakh soum of Dornogovi aimag, Mongolia

[redacted]